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Forest Tree Improvement Research in the Lake States

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U. S. DEPARTMENT OF AGRICULTURE

by

Paul O. Rudolf

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LAKE STATES FOREST EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE — FOREST SERVICE

The present summary of forest tree improvement projects in the region should be of considerable value in informing research workers and other interested people on what research is current in the Lake States, who is doing it, and where it is being done. It should also aid in encouraging and coordinating such research in the region. We are glad, therefore, to foster the work of the Lake States Forest Tree Improvement Committee by publishing another of its reports.

M. B. Dickerman

M. B. Dickerman, Director
Lake States Forest Experiment Station

FOREWORD

In June 1957 the Lake States Forest Tree Improvement Committee directed its Research, Evaluation, Coordination, and Planning (RECAP) Subcommittee to assemble project summaries for the agencies doing forest tree improvement research in Michigan, Minnesota, and Wisconsin. These summaries were to be coordinated with a national survey proposed by the Forest Genetics Research Foundation, if the latter were followed up. Later the Foundation decided to confine its report to the West; in November 1958 the report appeared as "Forest Genetics Research in the Rocky Mountain and Pacific Coast States and British Columbia."

The RECAP Subcommittee (R. A. Brink, University of Wisconsin; H. L. Mitchell, Forest Products Laboratory; Scott S. Pauley, University of Minnesota; Paul O. Rudolf, Lake States Forest Experiment Station; and Stephen H. Spurr, University of Michigan) directed its chairman to assemble, process, and distribute the report. In the interests of uniformity, it was decided to use the pattern of the Western report.

The Lake States report describes 113 research projects being conducted by 11 research agencies. It is believed that this survey gives a reasonably good account of present forest tree improvement research in the Lake States. By showing where we are, it may also help to chart the way we should go. The report is presented for the consideration of those conducting or supporting forest tree improvement research and of others interested in the research that is developing in the Lake States.

Some projects are being conducted by two or more research agencies. In this report they are listed for each such agency, but are described in detail only once. Where only the listing is used, reference is made to the project number where the detailed description is given. In addition a number of nonresearch agencies have aided the research projects through providing land, field help, nursery facilities, seed, and other items. They are listed as cooperators.

The RECAP Subcommittee gratefully acknowledges the assistance of the research agencies and workers who generously gave their time in preparing the project statements, of the Forest Genetics Research Foundation in stimulating this work and in setting a pattern for the report, and of the Lake States Forest Experiment Station in publishing this report.

Paul O. Rudolf

Paul O. Rudolf, Chairman
Research Evaluation, Coordination,
and Planning Subcommittee

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FOREST TREE IMPROVEMENT RESEARCH IN THE LAKE STATES

A Survey

by the Lake States Forest Tree Improvement Committee

Prepared by Paul O. Rudolf [1]

The Pattern of the Project Descriptions

In the following account each current forest tree improvement research project in the Lake States is described in a brief statement, prepared by the person in charge of the study and consisting of the title; a brief description of the objectives, methods, and accomplishments; a list of cooperators (if any); and the names of those responsible for the study.

Each statement bears two sets of numbers, one preceding and one following the title. The first is a reference number for identification of the project in cross-references and the indexes. It consists of two numbers separated by a hyphen; the first number identifies the research agency, and the second the project under that agency. Following the title are classification numbers showing the subject-matter category of the project. These categories accord with a classification prepared by Scott S. Pauley. The classification is given on page 48.

Each statement also shows the scientific names of the tree species being studied. Occasionally the word "General" is used instead of the species name to indicate broad projects applying to many genera.

1/ Chairman, Research Evaluation, Coordination, and Planning Subcommittee of the Lake States Forest Tree Improvement Committee; and Research Forester, Lake States Forest Experiment Station. The Station is maintained by the Forest Service, U. S. Department of Agriculture, at St. Paul 1, Minn., in cooperation with the University of Minnesota.

Agencies Conducting the Research

Code No.	Name
1	Consolidated Water Power and Paper Company
2	Institute of Paper Chemistry
3	Michigan State University, Forestry Department
4	Nekoosa-Edwards Paper Company
5	Quetico-Superior Wilderness Research Center
6	United States Agricultural Research Service, Plant Pest Control Branch
7	United States Forest Service, Forest Products Laboratory
8	United States Forest Service, Lake States Forest Experiment Station
9	University of Michigan, School of Natural Resources
10	University of Minnesota: School of Forestry, Department of Plant Pathology and Botany, Department of Entomology and Economic Zoology, and North Central School of Agriculture (Grand Rapids, Minn.)
11	University of Wisconsin, Departments of Genetics and Plant Pathology

Research Projects

1. Consolidated Water Power and Paper Company
P. O. Box 381, Rhinelander, Wisconsin

1-1. Super Spruce Planting. 111.3, 122. *Picea glauca*.

Object: To determine whether fast-growing white spruce nursery stock continues superior growth after being transplanted into the field; eventually to use this planting as a seed orchard if superior genetic characteristics appear to be involved.

Methods: Exceptionally fast-growing 2-2 white spruce stock was chosen from the company nursery and was planted in the field with controls.

Accomplishments: Eight-year measurements indicate a definite advantage in growth for the super stock. Approximately 20 percent of the regular stock trees also have very good growth.

Assignment: J. W. Macon, Forester.

2. The Institute of Paper Chemistry
Appleton, Wisconsin

2-1. Larch Improvement. 111, 112.01. *Larix decidua*, *L. decidua* var. *polonica*, *L. eurolepis*, *L. gmelini* var. *japonica*.

Object: To field-test proveniences of larch species and hybrids, as a partial evaluation of the suitability of this fast-growing high specific gravity conifer for intensive production of raw material for pulping and papermaking.

Methods: Stock of various sources was grown in the nursery and then outplanted.

Accomplishments: Seedlings have been planted out near Rhinelander, Wis., for tests of *Larix decidua*, *L. decidua* var. *polonica*, *L. gmelini* var. *japonica*, and *L. eurolepis*. Additional species and proveniences were seeded in the nursery in 1959.

Cooperators: Cornell Paperboard Products Co.; D. S. & R. H. Gottesman Foundation; Inland Container Corp.; Kimberly-Clark Corp.; Marathon, A Division of American Can Co.; Rhinelander Paper Co., A Division of St. Regis Paper Co.; Lake States Forest Experiment Station and National Forests in the Lake States; David B. Cook, Cooxrox Forest, N. Y.

Assignment: D. W. Einspahr, Physiologist.

2-2. Forest Tree Physiology. 151.02, 251.02. General.

Object: To investigate phases of plant physiology related to problems in tree breeding.

Methods: Rooting trials were made in the greenhouse; anatomical studies and chromatographic biochemical studies were made of changes associated with rooting and flowering.

Accomplishments: First studies of genetic variation in rootability from stem cuttings, and of seasonal influence on propagation from root cuttings were completed. Progress was made in relating anatomical and biochemical changes to rooting behavior of stem cuttings.

Assignment: J. P. van Buijtenen, Geneticist; and D. W. Einspahr, Physiologist.

2-3. The Application of the Pulping and Papermaking Sciences to the Genetic Improvement of Southern Pulpwood. 151.32. Pinus elliottii, P. taeda.

Object: To contribute to the genetic improvement of southern pulpwood a continuing fusion in research between (1) expanding fundamental knowledge about primary wood characteristics in relation to papermaking and (2) the full resources which genetics can furnish for the genetic study and improvement of these characteristics.

Methods: To date, analytical methods employed include those for measuring from core samples fiber strength and length, wood cellulose, lignin and total extractives, and pulp yield and permanganate number for loblolly pine and slash pine.

Accomplishments: Microscale pulping equipment and a method for evaluating fiber strength from increment cores were developed; these were applied to samples from a natural stand of loblolly pine.

Cooperators: The Riegel Paper Corp., The Union Bag-Camp Paper Corp., and The West Virginia Pulp and Paper Co.

Assignment: P. N. Joranson, Research Associate; and J. P. van Buijtenen, Geneticist.

2-4. Lake States Aspen Genetics and Tree Improvement Project. 211, 212, 251.32. Populus tremuloides, P. grandidentata.

Object: To explore and develop the genetic potential in aspen species for achieving maximum production of high-quality fiber for pulping and papermaking.

Methods: Promising breeding materials are sought through selection, hybridization (intra- and inter-specific), polyploid introduction, detection, synthesis and induction, and radiation-induced mutation. Wood properties which influence processing variables and properties of paper receive major attention through cooperation with other Institute departments. Methods of research include selection (selection index, study of variation, and heritability), polyploid induction, techniques of propagation by vegetative and sexual means, field establishment problems, wood property (anatomical, chemical, and physical) evaluation from small samples, wood property variation within the tree, chromosome counts.

Accomplishments: Superior aspen phenotypes, including natural triploids were discovered; variation in nature was studied; heritability was estimated; field tests of hybrids produced within and between species and of progeny from open-pollinated tree selections were established; a field study of possible relation between sex and certain tree characteristics was completed; rapid growth, long fibers, and increased paper tearing strength in triploids were demonstrated; methods were improved in most areas given above.

Cooperators: Cornell Paperboard Products Co.; D. S. & R. H. Gottesman Foundation; Inland Container Corp.; Kimberly-Clark Corp.; Marathon, A Division of American Can Co.; Rhinelander Paper Co., A Division of St. Regis Paper Co.; Lake States Forest Experiment Station and National Forests in the Lake States.

Assignment: P. N. Joranson, Research Associate; D. W. Einspahr, Physiologist; and J. P. van Buijtenen, Geneticist.

2-5. Investigation of the Effects of Gibberellic Acid on Growth and Fiber Dimensions in Quaking Aspen. 251.0. Populus tremuloides.

Object: To test the overall usefulness of gibberellic acid in improving wood quality and rate of growth in aspen.

Methods: Replicated greenhouse and field trials, involving approximately 1800 seedlings, were established. Measurements of survival, height and diameter growth, root development, leaf characteristics, and fiber length were the principal techniques used to evaluate treatment effects.

Accomplishments: Data have been taken, and are being evaluated.

Cooperators: Abbott Laboratories, North Chicago, Ill.

Assignment: D. W. Einspahr, Physiologist; and J. P. van Buijtenen, Geneticist.

2-6. Investigation of Soil Factors Important in the Growth of Aspens and Associated Tree Species. 251.4. Populus tremuloides and P. grandidentata.

Object: To investigate soil factors important in the growth of aspen and to evaluate the relative importance of soils, as opposed to heredity, in volume growth and wood quality.

Methods: Several site index-soil description areas have been established to evaluate the measurable soil properties important in the prediction of site quality for aspen. Field sampling of soils, leaves, wood, and tree growth are followed by laboratory investigation of soils, tissue, and wood samples.

Accomplishments: A reliable method for the prediction of the site index of heavy-textured soils has been obtained, and additional work is being carried out on the medium- and light-textured soils. The data from a preliminary study, designed to investigate the usefulness of chemical tests on leaf samples in predicting the fertility levels of forest lands, have been assembled. Results from this preliminary study will guide future work along this line. Apparent soils-wood quality relationships are being investigated further.

Assignment: D. W. Einspahr, Physiologist; and J. P. van Buijtenen, Geneticist.

3. Michigan State University, Forestry Department
East Lansing, Michigan

3-1. Evaluation of Exotics. 111.0. General.

Object: To determine, from past ornamental and forestry plantings, the best exotics for use in Michigan, those on which intensive genetic work should be started, and those which still need to be tested.

Methods: During the summer of 1958 work was started on the measurement of the rarer exotics in the southern part of Michigan. In each case the measured tree was paired (if possible) with a nearby closely related native species. This work is continuing, with the intention of getting out a large bulletin or book by 1962.

Assignment: J. W. Wright, Associate Professor; J. W. Andresen, Instructor.

3-2. Tests of Exotic Species. 111.0. General.

Object: To test the suitability of exotic forest tree species for Michigan.

Methods: Field tests have been established at the Dunbar Forest, the Kellogg Forest, and the Russ Forest.

Accomplishments: Observations have been made on the development of various species.

Assignment: Maurice W. Day, Assistant Professor; and Walter Lemmien, and S. W. McCullough, Foresters.

3-3. Geographic Variation in Japanese Larch. 111.1. *Larix leptolepis*.

Object: To determine: (1) the maximum range of genetic variation within the species and the pattern (ecotypic or clinal) of this variation, (2) the major environmental and population factors responsible for the genetic differentiation, (3) the best origins for planting in each of 10 localities in Michigan, and (4) the constancy of behavior of a given genotype under varying environmental conditions.

Methods: In the fall of 1957, 7 seedlots of known geographic origin with excellent source data were received from the Japanese Government Forest Experiment Station. These were sown in a 5-replicated randomized block design in the Bogue Nursery in early May 1958; a 6th replicate was broadcast-sown to furnish excess planting stock. The 5-replicated portion was thinned to approximately 16 trees per square foot as soon as damping-off danger was past. During 1958 and 1959 the seedlings were scored or measured (and statistically analyzed on the electronic computer) for 17 different characters. In the winter of 1958-59 25 seedlots of known origin were received from W. Langner at Schmalenbeck (via Fred Klaehn at Syracuse). These are part of an international test. The seeds were sown on May 14, 1959.

Accomplishments: Statistically significant differences among origins were found in the amount of winter killing, fall foliage color, spring foliage color, percent of trees winter-killed, and branchiness. No differences were found in first-year height, time of leafing out, or time of growth cessation. Plans for the coming year include nursery measurement and preparation of outplanting sites for the spring of 1961 and 1962.

Cooperators: Government Forest Experiment Station at Tokyo; Institut für Forstgenetik und Forstpflanzenzüchtung, Schmalenbeck; Lake States Forest Experiment Station; Michigan Conservation Department; University of Michigan.

Assignment: J. W. Wright, Associate Professor; J. G. Genys, Graduate Student.

3-4. Geographic Variation in White Spruce, White Pine, Virginia Pine, and European Larch. 111.1. *Larix decidua*, *Picea glauca*, *Pinus strobus*, and *P. virginiana*.

Object: To determine the best geographic origins for planting at each of two localities in Michigan and the relative amounts of local and geographic variation in these species.

Methods: During 1958 and 1959 2-0 or 2-2 stock of known geographic origin was received of *Picea glauca* (19 origins), *Pinus strobus* (16 origins), *Pinus virginiana* (16 origins), and *Larix decidua* (25 origins). Data on geographic origin were adequate for the *Larix* stock but scanty or nonexistent for the other seedlots. The stock was lined out in the Bogue Nursery and will be outplanted in 25-replicated randomized block designs in the spring of 1960.

Cooperators: Lake States Forest Experiment Station; Petawawa Forest Experiment Station; Northeastern Forest Experiment Station; Maryland Department of Education and Research; and the University of Michigan.

Assignment: J. W. Wright, Associate Professor; Walter Lemmien, Forester; and Maurice W. Day, Assistant Professor.

3-5. Geographic Variation in Scotch Pine. 111.1. *Pinus sylvestris*.

Object: To determine: (1) the maximum range of genetic variation within the species and the pattern (ecotypic or clinal) of this variation, (2) the major environmental and population factors responsible for the genetic differentiation, (3) the best origins for planting in each of 10 localities in Michigan, and (4) the constancy of behavior of a given genotype under varying environmental conditions.

Methods: In 1958 263 different seedlots were obtained from cooperators in Europe, most of the lots satisfying the requirements as to natural stands, number of parents, and desired origin. The seed samples were weighed and mounted on permanent herbarium sheets. The seeds were sown in a 4-replicated randomized block design in the Bogue Nursery on May 12 and 13, 1959.

Accomplishments: Germination was adequate except in 4 lots. By the 5th day the Spanish and Turkish proveniences could be recognized by hypocotyl size and foliage color. Plans for the coming year include a complete taxonomic monograph of the species, preparation of outplanting sites for planting in 1962, measurement of the nursery stock for at least 10 different characters, and statistical analysis of the data.

Cooperators: Numerous Europeans; the U. S. Forest Service; Michigan Conservation Department; and the University of Michigan.

Assignment: J. W. Wright, Associate Professor; J. W. Andresen, Instructor.

3-6. Geographic Variation in European Black Pine. 111.1. Pinus nigra.

Object: To determine: (1) the maximum range of genetic variation within the species and the pattern (ecotypic or clinal) of this variation, (2) the major environmental and population factors responsible for the genetic differentiation, (3) the best origins for planting in each of 10 localities in Michigan, and (4) the constancy of behavior of a given genotype under varying environmental conditions.

Methods: In 1958, 29 different seedlots of known geographic origin, about 20 of them from natural stands, were received from cooperators in southern Europe. The seeds were weighed and samples were mounted on herbarium sheets. The seeds were sown on May 13 and 14, 1959, in a 4-replicated randomized block design. Germination started on the 11th day and was nearly complete by the 16th day.

Accomplishments: By June 11, 1959, the progenies had been measured or scored and statistically analyzed for three different characters (germination speed, foliage color, size of primary needles). These characters were found to be uncorrelated with each other; statistically significant differences were found in all three. Plans for the coming year involve obtaining about 75 more progenies, initiating a complete taxonomic monograph of the species, and preparing outplanting sites for the spring of 1962.

Cooperators: Numerous Europeans; the U. S. Forest Service; Michigan Conservation Department; the University of Michigan.

Assignment: J. W. Wright, Associate Professor; J. W. Andresen, Instructor.

3-7. Intra-Ecotypic Selection for Shoot-Moth Resistance in Red Pine. 111.2. Pinus resinosa.

Object: To determine the selection and breeding program which will give the quickest results, and to develop a more shoot-moth resistant strain of red pine.

Methods: The methods of population genetics were used to prepare an analysis of probable genetic gains to be expected from different breeding procedures. This analysis indicated that, when listed according to order of increasing genetic gain, the possible breeding methods are: phenotypic (mass) selection (least gain), clonal selection, 1-parent progeny selection, 1-parent progeny selection plus clonal plantings, 1-parent progeny selection plus 2-parent matings, selection on basis of 2-parent progeny tests (most gain). Whenever there is a good seed year, seed will be collected from the selected parents and 100-replicated randomized block progeny tests established of the selected parents.

Accomplishments: Cost analyses indicate that clonal tests will cost at least 5 times (and probably 10 or more times) as much to establish as will 1-parent progeny tests. Considering cost, the balance is largely in favor of the 1-parent progeny tests. The cost analyses also indicate that 2-parent progeny tests are less expensive than clonal plantings--there the balance is all in favor of the use of 2-parent progeny selection. With these analyses in mind, phenotypic selection of superior (with regard to moth-resistance only) red pines were started in the fall of 1957; this is continuing.

Cooperators: Michigan Conservation Department.

Assignment: J. W. Wright, Associate Professor.

3-8. Tests of Forest Tree Hybrids. 112.01, 212.01. *Pinus* spp., *Populus* spp., and *Salix* spp.

Object: To test the suitability of several forest tree species hybrids for Michigan.

Methods: Field plantings of the hybrids were made on the Kellogg Forest.

Accomplishments: Observations have been made on the development of the various hybrids.

Cooperators: Pacific Southwest Forest Experiment Station; Northeastern Forest Experiment Station.

Assignment: Walter Lemmien, Forester.

3-9. Vegetative Propagation--Split Seedlings. 151.02. *Pinus nigra*, *P. resinosa*.

Object: To determine whether 2-ramet clonal tests can be established by splitting seedlings down the middle.

Methods: Most work on vegetative propagation has concentrated on rooting of cuttings, air layering, or grafting, on the supposition that economical methods of producing large numbers of ramets could be found and that the production of large numbers of ramets is desirable. For many groups these suppositions have still to be proved, as the vegetative propagation of special parents is justified only if the parents are sufficiently unusual; this uniqueness has hardly been studied--only assumed. For purposes of testing heritability, a 2-ramet clonal test would be sufficient. Following up work done elsewhere on rubber trees, southern pines, yellow-poplar, green ash, and red maple, 2-0 seedlings of Austrian and red pines were split down the middle, the cut surfaces waxed, the tops sprayed and the trees replaced in the nursery.

Accomplishments: Overall survival has been about 50 percent, indicating that a 200-clone test could be established with 2 or 3 man-days of splitting work.

Assignment: J. W. Wright, Associate Professor.

3-10. Plot Size and Shape in Forest Genetics Research. 153. General.

Object: To determine most efficient plot sizes and shapes for use in forest genetics field tests.

Methods: In each of six stands, the heights or diameters of up to 1,000 trees were measured and the variances among plots computed when the stand was considered to be composed of n one-tree plots, n/2 two-tree plots, n/3 three-tree plots, etc. Then the relative efficiency (measured by the relative amount of information per tree) was computed for the various plot sizes.

Accomplishments: It was found that in five of the six stands the conventional 50- or 100-tree plots were only about 10 to 20 percent as efficient as 1-tree plots would be. Optimum plot size, as calculated by the use of Fairfield Smith's methods, was found to vary from 1 to 2 trees if only growth measurements were to be made and from 4 to 20 trees per plot if chemical determinations of bulked samples from the plots were to be made. Plans for the coming year include extension of the work to about six other stands, the laborious calculations to be made on Michigan State's electronic computer. The work will also be extended into the nursery. Another aspect of the problem which will receive attention during the year is the evaluation of border effects where different species are planted side by side.

Assignment: J. W. Wright, Associate Professor; and F. D. Freeland, Assistant Professor.

4. Nekoosa-Edwards Paper Company
Port Edwards, Wisconsin

4-1. Lake States Jack Pine Seed Source Study. 111.1. *Pinus banksiana.*

Object: To study local performance of geographic seed sources as a guide in pulpwood planting programs.

Methods: Twenty-five Lake States seed sources were planted at Iron River and Nekoosa, Wis., in the spring of 1954 with 2-0 stock. Each area has three replicate plantations. Collections follow the subregions set up in the earlier Lake States red pine seed source study.

Accomplishments: First-year field survival and tree height were read. Losses were replanted in 1956. Fourth-year field survival, tree height, and disease and insect readings were made in 1958. Field readings are being summarized.

Assignment: B. L. Berklund, Forester.

4-2. Cooperative Regional Jack Pine Seed Source Study. 111.1. *Pinus banksiana.*

Object, Methods, Accomplishments: (See study 8-9 for details.)

Assignment: B. L. Berklund, Forester.

4-3. Lake States Red Pine Seed Source Study. 111.1. *Pinus resinosa.*

Object: To study local performance of geographic seed sources as a guide in pulpwood planting programs.

Methods: Twenty-five Lake States seed sources each were planted at Minocqua and near Nekoosa, Wis. Each area has three replicate plantations. Collections follow the seven subregions set up in the earlier Lake States Forest Experiment Station red pine seed source study.

Accomplishments: Plots were established in 1956 with 2-2 stock. First- and second-year field survival, tree height, and disease and insect observations have been taken and are being summarized. First-year losses were replanted.

Assignment: B. L. Berklund, Forester.

4-4. Lake States Black Spruce Seed Source Study. 111.1. *Picea mariana.*

Object: To study local performance of geographic seed sources as a guide in pulpwood planting programs.

Methods: Twenty-four Lake States sources were planted in three replicated plantations at Minocqua, Wis.

Accomplishments: Plots were established in 1956 and 1957 with 2-2 stock. First- and second-year field survival, tree height, and insect and disease observations have been taken and are being summarized. First-year losses were replanted.

Assignment: B. L. Berklund, Forester.

4-5. Lake States White Spruce Seed Source Study. 111.1. Picea glauca.

Object: To study local performance of geographic seed sources as a guide in pulpwood planting programs.

Methods: Twenty-three Lake States seed sources were planted in three replicated plantations at Minocqua, Wis. Not all sources occur in each replicate because of shortage of stock.

Accomplishments: Plots were established during 1956, '57, and '58 with 2-3 and 2-2 stock. First- and second-year survival, tree height, and insect and disease observations are in progress. First-year losses were replanted.

Assignment: B. L. Berklund, Forester.

5. Quetico-Superior Wilderness Research Center

Ely, Minnesota

5-1. Growth and Development of Exotic Conifers. 111.0. General.

Object: To determine the success of certain exotic species in this area, for use in tree improvement work.

Methods: Standard planting methods were used. Species planted include Norway spruce, Scotch pine, eastern hemlock, Douglas-fir, Engelmann spruce, white fir, blue spruce, European larch, ponderosa pine, and Austrian pine. Trees were planted during several years beginning in 1938.

Accomplishments: Survival and growth were determined after a 10-year period. A report on results was published:

Ahlgren, Clifford E. 1954. Growth and development of exotic species at the Quetico-Superior Wilderness Research Center. Quetico-Superior Wilderness Res. Center Tech. Note 2, 7 pp., illus.

Assignment: F. B. Hubachek, owner; Joseph Kerntz, project assistant; Clifford E. Ahlgren, Director.

5-2. Red Pine Seed Orchard Study. 122.1. Pinus resinosa.

Object: To determine techniques for use in field grafting elite red pine scions for the establishment of seed orchards.

Methods: 8- to 10-year-old red pine saplings were top-grafted, using the side-graft technique.

Accomplishments: Since 1954, 400 grafts have been made. Survival is 50 percent. Annual records of growth and flowering are maintained.

Cooperators: Iron Range Resources and Rehabilitation Commission of Minnesota.

Assignment: Clifford E. Ahlgren, Director.

5-3. Interspecific and Intergeneric Grafting. 151.02. Abies balsamea, Pinus cembra, P. koraiensis, P. peuce, P. resinosa, P. strobus.

Object: To determine the possible influence of rootstock of various species on the vegetative and reproductive growth of scions, and to investigate the possible establishment of exotic species for breeding work at the Center by grafting them onto native species.

Methods: Selected scions were top-grafted onto various native conifer rootstocks, 3 to 20 feet high.

Accomplishments: Since 1953, over 500 grafts have been made of the following combinations: Swiss stone pine on white pine, red pine, and balsam fir; Balkan pine on white and red pines and balsam fir; Korean pine on white and red pines and balsam fir; and white pine on red pine. Survival among many of the combinations is high and growth is good. Striking differences in rate of primary growth and flowering are becoming apparent among the various combinations.

Assignment: Clifford E. Ahlgren, Director.

5-4. Special Grafting Procedures. 151.02, 151.01. *Pinus resinosa, P. strobus*.

Object: To modify grafting techniques so as to change growth and flowering patterns.

Methods: The following techniques have been employed: (1) double working, or interstock grafting--scions of white pine were grafted onto interspecific grafts made 5 years previously; (2) inverted interstock grafting--a portion of scion wood was grafted in an inverted position and a second scion was grafted onto this in normal position; (3) inverted single scions--scions were side-grafted in an inverted position; (4) bark inversion--two rings of bark were inverted on the main stem of 2- to 4-foot red and white pines, leaving a band of bark intact between.

Accomplishments: 600 trees have been used in these flower induction experiments. The trees are examined and records made on flowering and growth. See also:

Ahlgren, Clifford E. 1958. Adventitious roots and shoots of wilding white pine at the Quetico-Superior Wilderness Research Center. Univ. of Minn. Forestry Notes, No. 70, 2 pp., illus.

Assignment: Clifford E. Ahlgren, Director.

5-5. Field Grafting of White Pine Selections. 151.02, 112.02. *Pinus strobus*.

Object: To develop a technique for field grafting, to establish flower-bearing wood for possible use in breeding, and to control-pollinate resultant cones.

Methods: Scions from selected parents were top-grafted onto natural white pine rootstocks 3 to 20 feet high and 8 to 20 years old at this Center. Scions were obtained from selections made with Drs. Riker and Patton of the University of Wisconsin.

Accomplishments: Over 700 grafts have been made. Controlled pollinations have been made annually since 1955. Seed from the crosses is sent to Dr. Patton for nursery growth.

Cooperators: University of Wisconsin, Department of Plant Pathology.

Assignment: Clifford E. Ahlgren, Director.

5-6. Blister Rust Inoculation by Bark Grafting. 151.02, 151.5. *Pinus strobus*.

Object: To develop a method to strengthen and speed-up the process of testing selections for resistance to blister rust.

Methods: A ring of diseased bark ½ inch wide was grafted onto the stems of both diseased and disease-free white pine trees 2 to 4 feet tall.

Accomplishments: Grafts were made in 1957 and 1958. Spread of the rust fungus beyond the graft has been noted in many cases.

Assignment: Clifford E. Ahlgren, Director.

5-7. A Test for Blister-Rust Resistance in Hybrid Seedlings and Seedlings Grown From Selected Parents. 151.5. *Pinus strobus*.

Object: To identify sources of resistance to blister rust.

Methods: Seedlings were planted in the Center's blister-rust test areas. Annual records of growth and infection are made.

Accomplishments: 500 hybrid and 500 control white pine seedlings were planted in 1955. Over 300 seedlings of the Basswood Lake selections were planted in 1956. All seedlings were started in the nursery by Dr. Patton of the University of Wisconsin.

Cooperators: University of Wisconsin, Department of Plant Pathology.

Assignment: Clifford E. Ahlgren, Director.

5-8. Tests for Blister-Rust Resistance in Root Grafts of Various White Pine Selections. 151.5. *Pinus strobus*.

Object: To identify native sources of resistance to blister rust.

Methods: Scions from native trees in northeastern Minnesota and Wisconsin which showed possible resistance to blister rust were root-grafted onto young seedlings in the Center's blister-rust test areas. The areas are situated on very good white pine sites where incidence of rust infection is very high.

Accomplishments: First tests contain 200 root grafts made by Drs. Riker and Patton at the University of Wisconsin. In the spring of 1959, 270 additional root grafts were made in one field on seedlings planted in 1958. A record of infection is maintained. A preliminary report was published in 1955:

Ahlgren, Clifford E. 1955. Grafted selections of eastern white pine tested for resistance to blister rust. Jour. Forestry 53: 727-729.

Cooperators: University of Wisconsin, Department of Plant Pathology.

Assignments: Clifford E. Ahlgren, Director.

6. United States Agricultural Research Service, Plant Pest Control Branch
St. Paul Campus, University of Minnesota, St. Paul 1, Minnesota

6-1. Vacuum Storage of Pollen. 154.02. *Picea abies*, *P. glauca*, *Pinus banksiana*.

Object: To determine ways of storing pollen with minimum loss of germination.

Methods: Pollen of jack pine, white spruce, and Norway spruce was stored under vacuum with chlorophyll, hemin, and sodium chelate of iron and without additives. A check sample was also stored in cotton-stoppered bottles in the refrigerator. Germination tests were made, using distilled water and 5-percent and 10-percent sucrose as media.

Accomplishments: At the end of 1 year, differences in germination between vacuum storage and normal atmospheric pressure storage were not significant.

Barber, John C., and Stewart, Donald M. 1957. Vacuum storage of pollen proves feasible. Univ. of Minn. Forestry Notes, No. 62, 2 pp.

Cooperators: University of Minnesota, School of Forestry.

Assignment: Donald M. Stewart, Plant Pathologist.

7. United States Forest Service, Forest Products Laboratory
Madison 5, Wisconsin

7-1. Wood Quality Evaluations for Genetics Studies. 151.32, 251.32. General.

Object: To provide overall evaluations of density and fiber characteristics in wide samplings such as Forest Surveys to assist in determining individual tree variations and outstanding or superior wood quality.

Methods: Specific gravity, summerwood percentages, and fiber characteristics were determined in cooperation with genetics and silvicultural studies at

Research Centers of the Forest Experiment Stations.

Accomplishments: Specific gravity comparisons have been completed, and fibril angle measurements on open-grown versus closely grown ponderosa pine are in progress. The density evaluations of southern pines were completed in Mississippi including about 8,000 trees described in three reports:

Mitchell, H. L. 1958. Wood quality evaluation from increment cores. Tappi 40(4): 150-156, illus.

Mitchell, H. L., and Wheeler, P. R. 1959. Wood quality of Mississippi's pine resources. U. S. Forest Serv., Forest Prod. Lab. Rpt. 2143, 20 pp., illus.

Wahlgren, H. E., and Fassnacht, D. L. 1959. Estimating tree specific gravity from a single increment core. U. S. Forest Serv., Forest Prod. Lab. Rpt. 2146, 24 pp., illus.

Similar work is being extended to the States of Arkansas, Missouri, and Florida. These studies not only show some outstanding individuals with exceptional wood quality but also help to designate areas of exceptional growth and density.

Cooperators: Southern, Southeastern, Lake States, and Pacific Northwest Forest Experiment Stations.

Assignment: M. Y. Pillow, Supervisory Technologist.

7-2. Wood Density of Red Pine From Geographic-Climatic Seed Sources. 151.321. Pinus resinosa.

Object: To determine the variations in increment core specific gravity within and between seed sources as a possible indicator of wood quality related to seed source variations.

Methods: All the trees from each of 50 seed sources present on each of the 8 plots were sampled by randomly oriented increment cores. The dry mass of wood will be estimated from the increment core specific gravity and the volume of a nominal pulpwood bolt at the breast height diameter. The analysis will include the effects of height and diameter growth and summerwood percentages in seeking differences among the 50 seed sources replicated on 8 plots.

Accomplishments: Specific gravity has been completed on about 340 of 3,000 trees.

Cooperators: Northeastern Forest Experiment Station.

Assignment: M. Y. Pillow, Supervisory Technologist; and H. E. Wahlgren, Project Technologist.

7-3. Evaluation of Wood Characteristics of White Ash From Different Seed Sources. 251.32. Fraxinus americana.

Object: To determine specific gravity, dry mass of wood, and fiber characteristics, particularly fibril angles, as indications of geographic or ecotypic variations.

Methods: Selected seed sources of white ash saplings outplanted at the Morris Arboretum, Philadelphia, Pa., have been sampled. Specific gravity and dry mass were determined for the first 6 of 8 years' height growth. Fibril angles and fiber lengths will be determined on the 1957 and 1958 years' radial growth in the 1956 height growth.

Accomplishments: Even though there were small differences in specific gravity, the larger variations were related in dry mass as a result of much greater or lesser height and diameter growth in the saplings. No clear trends between seed sources were shown by the initial analysis of density and growth characteristics.

Cooperators: Northeastern Forest Experiment Station.

Assignment: M. Y. Pillow, Supervisory Technologist; and Charlotte Hiller and L. E. Lassen, Technologists.

7-4. Wood Quality of Superior Hybrid Poplar Clones. 251.32. *Populus* spp.

Object: To determine density and tension wood occurrences in selected clones of hybrid poplars being tested in the Northeastern States.

Methods: Samplings are made by 1-foot cross-sections at breast height of thinned trees to determine specific gravity and dry mass of wood in a nominal pulpwood bolt from butt of the trees from 10 selected clones planted at Beltsville, Md., and Hopkins, Mass. The samplings are made during the periodic thinnings of 100 tree plantations, after which the 13 crop trees will be evaluated by increment core samples.

Accomplishments: Work plans were completed and the procedures established during 1959.

Cooperators: Northeastern Forest Experiment Station.

Assignment: M. Y. Pillow, Supervisory Technologist; H. E. Wahlgren and D. Pronin, Technologists.

7-5. Improvement of Wisconsin Poplars by Wood Quality Evaluations of Clones. 251.321. *Populus* spp.

Object: To evaluate specific gravity and dry mass of wood in introduced and native selections and hybrid seed progeny and clones designated because of superior resistance to pests and growth potentials on various sites.

Methods: Specific gravity and dry mass of wood were sampled by increment cores and by whole-tree determinations on outplanted poplar progenies. Pulping evaluations also will be made ultimately, using single-tree sampling to discover the potentialities of tree variations.

Accomplishments: Thirty trees of 12 different clones were sampled in 1958 on an increment core and a whole-tree basis to provide a basis for estimating dry mass data from the nondestructive increment core samplings.

Cooperators: University of Wisconsin, Departments of Plant Pathology, and Forestry and Wildlife.

Assignment: M. Y. Pillow, Supervisory Technologist; and Graduate Students.

7-6. Tension Wood Formation in Bent Hybrid Poplars. 251.325. *Populus* spp.

Object: To determine whether there are significant differences in the occurrences of the gelatinous fibers of tension wood among selected clones of hybrid poplars.

Methods: Three saplings from each of 10 clones will be bent to a maximum of about 12 degrees from the vertical and held in that position for 3 years. Since the amount of bending will be continuously variable, examinations will determine the occurrences of gelatinous fibers before and after bending in at least three positions between 1 and 6 feet above the ground.

Accomplishments: Installation of the study in 1959.

Cooperators: Northeastern Forest Experiment Station.

Assignment: M. Y. Pillow, Supervisory Technologist; and L. E. Lassen, Technologist.

8. United States Forest Service, Lake States Forest Experiment Station
St. Paul Campus, University of Minnesota, St. Paul 1, Minnesota

8-1. Denbigh Plantations. 111.0, 211.0. General.

Object: To test the feasibility of forest planting in the sandhills of McHenry County, N. Dak.

Methods: Between 1931 and 1942 stock of some 40 tree species of known seed origins was planted on 270 acres of sandhill area, using different methods of ground preparation and different intensities of aftercare. Periodic observations have been made on survival and development.

Accomplishments: The most promising species appear to be Pinus ponderosa, Juniperus virginiana, J. scopulorum, Pinus banksiana, P. sylvestris, Larix sibirica, L. laricina, Picea glauca, and P. pungens among the conifers, and Populus deltoides, Fraxinus pennsylvanica, Acer negundo, Quercus macrocarpa, and Ulmus pumila. Thorough ground preparation and annual cultivation for at least 5 years are necessary for successful establishment.

Cooperators: North Dakota State School of Forestry.

Assignment: Paul E. Slabaugh, Research Forester.

8-2. Spruce Species and Seed Source Study. 111.0, 111.1. Picea abies, P. glauca, P. glehni, P. mariana, P. obovata, P. omorika, P. orientalis, and P. rubens.

Object: To study the development of spruce of several species and seed sources in northeastern Wisconsin and to assemble breeding material of known origin.

Methods: White spruce of 7 seed origins, Norway spruce of 6 seed sources, red spruce of 2 seed sources, and 1 source each of Sakhalin, Siberian, Oriental, Serbian, and black spruces were grown in the nursery at Rhinelander, Wis., and field-planted in 5 localities in the northern Lake States in the spring of 1936. The severe drought of 1936 eliminated all but the block in northeastern Wisconsin. Periodic observations of survival and development have been made upon it.

Accomplishments: A report on 16-year development is in preparation.

Assignment: R. A. Ralston, Research Forester; Hans Nienstaedt, Geneticist; and Paul O. Rudolf, Research Forester.

8-3. White Pine Blister Rust Race Study. 111.1, 151.5. Pinus flexilis, P. koraiensis, P. peuce, P. strobus, Ribes spp.

Object: To determine whether there are races of white pine blister rust that vary in pathogenicity on pine. If such races are found, then an attempt will be made to identify these races as to infection pattern, host reaction, distribution, and relative abundance.

Methods: Aeciospore collections from throughout the range of white pine are sent to St. Paul and tested by first inoculating on Ribes leaves. The resultant infections are evaluated to detect evidence of genetic difference between two or more collections. Material which exhibits racial difference on Ribes is then tested on pine. The tests on pine are limited to those collections which show promise on Ribes because of the long waiting period necessary before results are obtained from pine inoculations.

Accomplishments: A large temperature and humidity chamber has been constructed in the greenhouse for use when temperatures are too high for rust development. Within the chamber, inoculation work can be continued throughout the summer months.

Clonal lines of Balkan, Korean, limber, and eastern white pines have been developed by grafting. These will be used to test rust collections that have shown reaction differences on Ribes. Only limited work has been done on inoculating pine but plans are to concentrate on this phase of the problem during the coming year.

Cooperators: University of Minnesota, Plant Pathology Department; U. S. Forest Service, Blister Rust Control Organization.

Assignment: Gerald W. Anderson, Research Forester; Ralph L. Anderson, Plant Pathologist.

8-4. European Larch Seed Source Test. 111.1. Larix decidua, L. laricina, L. leptolepis, L. sibirica.

Object: To determine the variation between European larches of several known seed origins and to assemble breeding material of these origins.

Methods: European larch seed of 11 origins and 1 origin each of Siberian and Japanese larches were received from the International Union of Forest Research Organizations in 1945 and were sown in the Eveleth Nursery in Minnesota in May 1946. In the spring of 1949 trees of each lot were field-planted in north-central Minnesota, northeastern Wisconsin, and central Lower Michigan. Periodic observations of growth and development have been made.

Accomplishments: Source-related differences were noted after 5 years in the field, with some European larches making better growth but poorer survival than native tamarack planted as a comparator in northern Minnesota and Wisconsin. Survival in general has not been very high; most of the mortality occurred the first year.

Cooperators: International Union of Forest Research Organizations.

Assignment: R. A. Ralston, Paul O. Rudolf, and Z. A. Zasada, Research Foresters.

8-5. Seed Source Study of Blue Spruce in North Dakota. 111.1. Picea pungens.

Object: To test blue spruce of several known seed origins in Northern Plains shelterbelts.

Methods: Blue spruce transplants of seven origins, ranging from Arizona to northern Wyoming, will be planted in two North Dakota shelterbelts in 1960. The stock, now in the State Nursery at Rhinelander, Wis., was received from the University of Minnesota. The trees will be planted in rows between a row of deciduous trees and a row of shrubs. The trees will be cultivated for 5 years. They will be examined after 1, 2, 5, 10, 15, and 20 years in the field for survival, growth, crown development, and foliage color.

Accomplishments: Stock was obtained from the Cloquet Nursery of the University of Minnesota and transplanted in the Hugo Sauer State Nursery at Rhinelander, Wis.

Cooperators: University of Minnesota, School of Forestry; and North Dakota State Forester.

Assignment: Paul E. Slabaugh and Paul O. Rudolf, Research Foresters.

8-6. White Spruce Racial Variation Test, Toumey Nursery. 111.1. Picea glauca.

Object: To supplement the range-wide white spruce seed source study by determining the occurrence of morphological and physiological races in white spruce of several Ontario and Quebec sources.

Methods: White spruce seedling stock from 19 Ontario and Quebec origins was obtained from the Petawawa Forest Experiment Station in May 1956, and transplanted in the nursery at Rhinelander, Wis. In the spring of 1958 the transplants were set out in two randomized blocks adjacent to the Toumey Nursery near Watersmeet, Mich. Growth and development will be measured periodically.

Accomplishments: Field plots were established in 1958.

Cooperators: Petawawa Forest Experiment Station; Ottawa National Forest.

Assignment: Hans Nienstaedt, Geneticist.

8-7. Ecotypic Variation in White Spruce Growing in Zones With Different Lengths of Growing Season in the Upper Peninsula, Michigan. 111.1. Picea glauca.

Object: To determine (1) whether distinct white spruce ecotypes have evolved as a result of climatic diversity in the central Upper Peninsula, (2) the relative dry-matter production efficiency of long- and short-growing season seed sources, and (3) the relative importance of photoperiod and temperature in determining the length of the growth period.

Methods: White spruce stands in the central Upper Peninsula were selected in zones with about 80-, 110-, and 140-day growing seasons. Seeds were collected from three stands in each zone, and seedlings have been grown in the greenhouse under controlled temperatures and daylengths. If these tests indicate ecotypic differences, field progeny tests will be made and phenological observations will be carried out on the parent stands.

Accomplishments: Greenhouse studies under controlled conditions have been conducted for 2 years; a nursery test was established in the spring of 1959.

Assignment: Hans Nienstaedt, Geneticist; Philip R. Larson, Plant Physiologist; Carl Arbogast, Jr., Research Forester.

8-8. A Study of Racial Variation in White Spruce. 111.1. Picea glauca.

Object: (1) To develop a sound basis for intraspecific hybridization of white spruce through the study of morphological and physiological variation throughout the range of the species; (2) to determine correlation between juvenile and mature growth of the trees; and (3) to collect a diversity of germ plasm for improvement work.

Methods: White spruce seed from 29 localities over the botanical range were collected and are growing in the nursery. They will be outplanted as 2-2 stock in at least four localities in the Lake States. Observations will be made in the nursery and in the field to determine any differences in growth, survival, development, and reaction to injurious agencies that may be associated with origin.

Accomplishments: Part of each seed lot was sown in the Hugo Sauer Nursery in northeastern Wisconsin in the spring of 1958, and observations have been made on germination and height growth above the cotyledons.

Cooperators: Petawawa Forest Experiment Station; Bureau of Land Management (Alaska); Northeastern Forest Experiment Station; Manitoba Forest Service.

Assignment: Hans Nienstaedt, Geneticist; Paul O. Rudolf, Research Forester.

8-9. Regional Jack Pine Seed Source Study in the Lake States. 111.1. Pinus banksiana. (Planned jointly with the University of Minnesota School of Forestry.)

Object: To determine whether (1) there are important and heritable racial differences in jack pine within the Lake States, (2) local, native seed sources are generally best, and (3) there are superior seed sources that may be better than local sources in some localities.

Methods: In 29 localities in the Lake States seed was collected from good stands of jack pine in 1951-52; stock was grown in State nurseries in Wisconsin and Minnesota and field-planted as 2-0 seedlings in the spring of 1954 in 17 localities in the 3 States. Fail spots were replanted in 1955. Examinations were made at the end of the first, second, and fifth growing seasons in the field. Special examinations were made on some plantations during intervening years.

Accomplishments: Fifth-year examinations are beginning to show some origin-associated differences in growth, insect damage, and disease susceptibility.

Cooperators: University of Minnesota; Conservation Departments of Minnesota, Wisconsin, and Michigan; National Forests of the Lake States; Nekoosa-Edwards Paper Co.; Mosinee Paper Mills Co.; University of Michigan; Burnett and Marinette Counties, Wis.

Assignment: Paul O. Rudolf, Research Forester; Hans Nienstaedt, Geneticist; and Thomas D. Rudolph, J. L. Arend, Carl Arbogast, R. A. Ralston, and Z. A. Zasada, Research Foresters; cooperators.

8-10. Lammas Growth and Prolepsis in Jack Pine. 111.1, 111.3, 151.0, 151.3. *Pinus banksiana*.

Object, Methods, and Accomplishments: (See study 10-8 for details.)

Cooperators: University of Minnesota, School of Forestry.

Assignment: Thomas D. Rudolph, Research Forester.

8-11. Red Pine Seed Source Study, Plot 99. 111.1. *Pinus resinosa*.

Object: To explore racial variation in red pine from the Lake States.

Methods: Transplant (2-1) stock grown from red pine seed of 48 Lake States and 3 northeastern United States sources was field-planted on the Pike Bay Experimental Forest (north-central Minnesota) in the spring of 1937. (Replicates of most lots were planted at the same time by the Northeastern Station on the Kane Experimental Forest in Pennsylvania.) Periodic observations of survival and development have been made, and the stand was thinned in 1951 and 1956.

Accomplishments: Data are being analyzed.

Cooperators: Northeastern Forest Experiment Station.

Assignment: Z. A. Zasada and Paul O. Rudolf, Research Foresters.

8-12. Camp-8 Red Pine Seed Source Study. 111.1. *Pinus resinosa*.

Object: To explore the morphological and physiological variation in red pine assembled from much of its natural range.

Methods: Red pine seed was collected from native trees in more than 150 localities over the Lake States, the Northeast, and Canada. Stock was grown at the Cass Lake Nursery, Minn., and was field-planted in three localities in 1931 (37 sources) and 1933 (154 sources). Only the northeastern Minnesota plantation escaped drought and fire damage. On it, observations of growth and development have been made periodically and will be continued.

Accomplishments: A report on results 21 years after planting is in preparation. Earlier results showed source-related differences in survival and development, with northeastern United States, Lower Michigan, and central Wisconsin sources generally poorer than those from localities closer to the planting site in northeastern Minnesota. Publications issued include:

Rudolf, Paul O. 1947. Importance of red pine seed source. Soc. Amer. Foresters Proc. 1947: 384-398, illus.

______. 1948. Local red pine seed develop best plantations. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 296, 2 pp.

______. 1951. Nursery behavior of red pine stock of different seed origins. U. S. Forest Serv. Tree Planters' Notes 8: 3-4.

______. 1954. Seed source and earliness of shoot growth in young red pine seedlings. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 423, 2 pp.

Assignment: Z. A. Zasada and Paul O. Rudolf, Research Foresters.

8-13. Interregional Provenience Study of Eastern White Pine. 111.1. *Pinus strobus*.

Object: (1) To clarify the magnitude and nature (clinal or discontinuous) of genetic diversity in eastern white pine, and (2) to determine which proveniences are best adapted to different sections of the Lake States.

Methods: Eastern white pine seed was collected from 17 localities over the botanical range of the species. Stock from 13 of these sources will be grown by various cooperators in Canada, the Lake States, the Northeast, the Central States, and the Southeast. Some plantings in each region will follow a standard plan. Others may follow alternative plans. Observations of survival and development will be made in the nursery, at 1, 2, and 5 years after planting, and at intervals thereafter.

Accomplishments: Seed of 17 sources was sown in the U. S. Forest Service Nursery at Watersmeet, Mich., in the spring of 1958. Because of poor germination of some lots, supplemental sowings were made in the spring of 1959 at the Hugo Sauer State Nursery at Rhinelander, Wis. Some source-related differences in growth appeared during the first year in the nursery.

Cooperators: Ontario Department of Lands and Forests; Northeastern Forest Experiment Station; Central States Forest Experiment Station; Southeastern Forest Experiment Station; Michigan College of Mining and Technology; Quetico-Superior Wilderness Research Center; and Ottawa National Forest.

Assignment: Hans Nienstaedt, Geneticist; and Paul O. Rudolf, J. L. Arend, Carl Arbogast, Jr., R. A. Ralston, and Z. A. Zasada, Research Foresters.

8-14. International Union Source of Seed Study. 111.1. Picea abies, Pinus sylvestris.

Object: To explore the variation in Scotch pine and Norway spruce of several origins when planted in the Lake States and to accumulate breeding material of known origin.

Methods: Scotch pine and Norway spruce seed were collected from stands throughout Europe by the International Union of Forest Research Organizations in the late 1930's. From this 10 lots of Scotch pine and 14 lots of Norway spruce were sown in the nursery at Cass Lake, Minn., in 1938. Field plantings of this stock were made in the spring of 1941 in north-central Minnesota and west-central Lower Michigan. Observations on growth and survival have been made.

Accomplishments: In Lower Michigan, 15 years after planting, differences between sources in survival and development were evident. Some sources from Poland seemed best for both species on the basis of survival and height development combined.

Slabaugh, Paul E., and Rudolf, Paul O. 1957. The influence of seed source on the development of Scotch pine and Norway spruce planted in Lower Michigan (15-year results). Mich. Acad. Sci., Arts & Letters Papers (1956) 42: 41-52, illus.

Rudolf, Paul O., and Slabaugh, Paul E. 1958. Growth and development of 10 seed sources of Scotch pine in Lower Michigan (15-year results). U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 536, 2 pp.

_______ and _______. 1958. Growth and development of 12 seed sources of Norway spruce in Lower Michigan (15-year results). U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 537, 2 pp.

Cooperators: International Union of Forest Research Organizations.

Assignment: J. L. Arend, Paul O. Rudolf, and Z. A. Zasada, Research Foresters.

8-15. Hemlock Racial Variation Test, Argonne Experimental Forest. 111.1. Tsuga canadensis.

Object: To explore variation, particularly in morphological and physiological characteristics, over the entire range of eastern hemlock.

Methods: Eastern hemlock seeds of known origin were assembled by The Connecticut Agricultural Experiment Station in 1953 and grown there as 1-2 stock. In the spring of 1957, stock of 16 origins was transplanted at the Hugo Sauer Nursery near Rhinelander, Wis.; it was field-planted in the spring of 1958 on the Argonne Experimental Forest.

Accomplishments: Field plots were established in 1958. Nursery observations indicated some differences in frost damage in northeastern Wisconsin.

Nienstaedt, Hans. 1958. Height growth is indicative of the relative frost resistance of hemlock seed source. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 525, 2 pp., illus.

Cooperators: The Connecticut Agricultural Experiment Station.

Assignment: Hans Nienstaedt, Geneticist.

8-16. Jack Pine-Lodgepole Pine Hybrids. 112.01. Pinus banksiana, P. contorta.

Object: To test crosses of jack pine with lodgepole pine along with the two parent species at several localities in the Lake States.

Methods: The seed was produced at the Western Institute of Forest Genetics at Placerville, Calif. The stock, grown at the Hugo Sauer Nursery in Wisconsin, was field-planted in the spring of 1953 in north-central Minnesota, northeastern Wisconsin, and central Lower Michigan in small replicate lots. Included were lodgepole pine of California origin, jack pine of Wisconsin origin, three crosses between the two (with P. banksiana the pollen parent), the backcross of the hybrid to jack pine and the backcross of the hybrid to lodgepole pine.

Accomplishments: Five-year examinations indicate distinct differences in growth and survival between the various lots and between localities. In general, jack pine has made the best growth and lodgepole pine the poorest, with the backcross to jack pine second best, the F_1 hybrids next, and the backcross to lodgepole pine next to the poorest. In survival the hybrids have done as well as or better than jack pine. Rust infection follows the same pattern as height growth, with lodgepole pine severely infected.

Cooperators: Pacific Southwest Forest Experiment Station.

Assignment: Z. A. Zasada, R. A. Ralston, J. L. Arend, and P. O. Rudolf, Research Foresters.

8-17. Eastern White Pine-Western White Pine Hybrids. 112.01. Pinus monticola, P. strobus.

Object: To test crosses of eastern white pine with western white pine along with the two parent species at several localities in the Lake States.

Methods: The seed was produced at the Western Institute of Forest Genetics at Placerville, Calif. The stock, grown at the Hugo Sauer Nursery in Wisconsin, was field-planted in small lots in the spring of 1954 in north-central Minnesota, northeastern Wisconsin, and central Lower Michigan. Included were western white pine of California and Idaho origins, eastern white pine of Wisconsin and New Hampshire origins, and five crosses of the two species (with P. strobus the pollen parent in each instance). One lot of local eastern white pine was planted in each plantation.

Accomplishments: Five-year examinations indicate distinct differences in growth and survival, with eastern white pine generally best, the hybrids intermediate, and western white pine poorest. Results in the three localities differ, but the general pattern is similar. The hybrid with the Idaho western white pine parent has outgrown that with the California western white pine parent.

Cooperators: Pacific Southwest Forest Experiment Station.

Assignment: Z. A. Zasada, R. A. Ralston, J. L. Arend, and P. O. Rudolf, Research Foresters.

8-18. Seed Crop Reports. 122, 222. General.

Object: To obtain a systematic record of seed production of the more important forest tree or shelterbelt species in several localities in the Lake States and North Dakota.

Methods: Beginning in 1946 annual observations have been made, each winter, of the seed crop (in proportion of a full crop) for the important tree species in each research center territory of the Lake States Forest Experiment Station.

Accomplishments: The annual seed crop reports have been published since 1949 by the Lake States Forest Experiment Station as Technical Notes 333, 349, 370, 393, 412, 426, 447, 501, 540, and 565.

Assignment: Paul O. Rudolf, J. L. Arend, Carl Arbogast, Jr., R. A. Ralston, Paul E. Slabaugh, and Z. A. Zasada, Research Foresters.

8-19. Springwood-Summerwood Transition Studies in Red Pine Seedlings. 151.0, 151.32. *Pinus resinosa.*

Object: To determine (1) the relationship between the cessation of terminal elongation and the transition of springwood to summerwood, and (2) the effect of exogenous applications of auxin on growth ring formation in decapitated seedlings.

Methods: Potted red pine seedlings were held under long-day and short-day conditions and combinations of these two conditions with and without applications of auxin. Summerwood development was determined by dissection of the seedlings.

Accomplishments: Preliminary results indicate that the springwood-summerwood formation in red pine is regulated by the terminal meristem. In general, growth conditions that favor high auxin synthesis promote springwood formation, and those that favor low auxin synthesis promote summerwood development. The study is being extended to investigate more intensively the mechanisms controlling cell diameter and cell wall thickness to shed more light on the nature of the regulatory stimuli and their modes of action.

Assignment: Philip R. Larson, Plant Physiologist.

8-20. Fall Grafting of Spruce. 151.02. *Picea glauca.*

Object: To develop a reliable grafting method for white spruces of seed-bearing age during the time of seed harvest in the fall.

Methods: Scions of white spruce of two ages of wood from 30- to 60-year-old trees were collected in the fall and grafted by three methods on potted stock plants of Norway and white spruces. Stock plants were given different day-length treatments before grafting and the grafted plants, long-day and natural-day treatments after grafting.

Accomplishments: Survival was 70 to 100 percent and showed effects of rootstock and postgrafting treatments in a few cases only. Photoperiod and temperature treatments after grafting, however, had considerable effect on scion activity and total growth. The best postgrafting treatment was 4 weeks of long-day followed by 2 weeks of short-day, then 8 weeks chilling, and finally long-day. Results are included in the following publications:

Nienstaedt, Hans; Cech, Franklin B.; Mergen, Francois; Wang, Chi-Wu; and Zak, Bratislav. 1958. Vegetative propagation in forest genetics research and practice. Jour. Forestry 56: 826-839, illus.

_______. (In press.) The effect of rootstock activity on the success of fall grafting of spruce. Jour. Forestry.

Assignment: Hans Nienstaedt, Geneticist.

8-21. Influence of Complete Fertilizer Applications in Plantations Infested by the European Pine Shoot Moth. 151.03, 152.0, 122.1. *Pinus resinosa.*

Object: To determine if granular fertilizers will influence the ability of trees to withstand attacks by the insect.

Methods: Fertilizers will be applied broadcast at rates of 50 and 100 pounds per tenth acre in stands which are on sandy soils of low fertility and which have been heavily infested for more than 5 years. Periodic field examinations will assess tree growth and insect damage.

Accomplishments: This study was initiated in April 1959.

Cooperators: Michigan State University, and Allied Chemical Company.

Assignment: H. J. Heikkenen and R. L. Talerico, Entomologists.

8-22. A Study of the Growth of Four Northern Conifers in a Southern Nursery With Long-Day. 151.04, 154.2. *Picea glauca*, *P. mariana*, *Pinus resinosa*, *P. strobus*.

Object: To study the growth and development of red and white pines and black and white spruces of Lake States origin in a north Florida nursery under natural and 20-hour day and to compare this stock with that grown from identical seed lots in northeastern Wisconsin under natural and 20-hour day.

Methods: Black spruce, white spruce, red pine, and eastern white pine seed were obtained from stand collections in the fall of 1957. Part of the seed was sown in the Olustee Experimental Forest Nursery, Florida, in December 1957. Artificial lighting commenced as soon as germination began and continued until 4 weeks before the average date of the first killing frost. The second season, lighting started soon after the start of extension growth and will cease on the same date as in the first year. A second part of the seed was sown in the Hugo Sauer State Nursery, Wis., in the spring of 1958 in an identical experimental design. A high nutrient level is being maintained at both nurseries. Measurements of the growth and development of the stock are made at frequent intervals.

Accomplishments: Results of the first year's treatment showed considerable size advantage for white pine grown under long-day in the southern nursery. Red pine responded well to the long-day treatment in the South, but survival was low. The other species showed less response during the first season. Early results of the second season in the South promise even greater advantage over the northern planting.

Cooperators: Southeastern Forest Experiment Station; Wisconsin Conservation Department; and University of Minnesota.

Assignment: R. F. Watt, Research Forester.

8-23. Chilling Requirements for Breaking Bud Dormancy in White Spruce. 151.04, 151.05. *Picea glauca*.

Object: To determine (1) the minimum chilling requirements of white spruce seedlings, and (2) if long-day treatments compensate for these chilling requirements.

Methods: One-year or two-year seedlings of white spruce dug after the terminal buds had stopped elongating in late July or early August were potted. Part were placed in the greenhouse; and part in cold storage at natural daylength (13-hour), removed to the greenhouse after 2 to 16 weeks' cooling at 36° F., and then held at natural or long daylength (20-hour). Observations were made on bud swelling, exposure of needles, and beginning of terminal elongation. Another set of seedlings was potted in mid-September and exposed to the same treatments.

Accomplishments: Results so far indicate that to break dormancy of white spruce plants on 13-hour daylength requires 6 to 8 weeks of chilling if treatments begin in July and 4 to 6 weeks if begun in September. Long-day treatments compensated fully for lack of chilling in the July series but were not quite as effective in the September series.

Assignment: Hans Nienstaedt, Geneticist; Philip R. Larson, Plant Physiologist.

8-24. Phenology of White Spruce. 151.08. Picea glauca.

Object: For white spruce, to (1) determine and describe the developmental stages in flower formation during the period of pollination, (2) determine the time interval between pollination and fertilization, and (3) determine the first appearance of primordial male and female flowers and follow their development through one complete cycle.

Methods: (1) From March 15 to the end of pollination, records will be kept of bud swelling, flower extension, stalk elongation, strobili position, cone scale position, color of strobili, beginning and end of pollen shedding; (2) female strobili will be collected semiweekly between 1 week and 8 weeks after pollination, fixed in F.A.A. solution, embedded in paraffin, sectioned, and examined under the microscope; and (3) buds and young shoots will be collected at intervals during the growing season, fixed in F.A.A., and sectioned for examination under the microscope.

Accomplishments: About 400 slides of the initial stages of flower formation in white spruce have been prepared for scrutiny under the microscope to determine the earliest possible time during the season at which flower primordia can be distinguished.

Assignment: Hans Nienstaedt, Geneticist.

8-25. Auxin-Summerwood Relationships in Physiologically Mature Red Pine. 151.32, 151.0. Pinus resinosa.

Object: To determine whether or not a correlative relationship exists between auxin metabolism and the initiation of summerwood formation in red pine.

Methods: Red pine branch samples were collected from the upper one-third of the crown in 15 vigorous, full-crowned trees 25 to 35 years old, at regular intervals between mid-May and mid-August. The branches were segmented into the bud or growing point, the current internode, and the previous year's internode. Within 3 hours after collection auxin was ether-extracted from the bud and the current internode and bioassays were made. Anatomical observations of summerwood development were made of typical specimens at each collection date. Observations on growth and development were made at each date.

Accomplishments: Data and observations have been accumulated for analysis.

Assignment: Philip R. Larson, Plant Physiologist.

8-26. A Study of Insects Affecting Coniferous Seed Production in the Lake States. 152.0. General.

Object: To determine the insect species responsible for damage to flowers, seeds, and cones of the various species of coniferous trees in the Lake States; to determine the life history and habits of the major pest species and the extent of this damage; to determine and evaluate natural factors of control; and to develop effective and economical methods of direct and indirect control.

Methods: Cones and male flowers of conifers will be caged at regular intervals in the field to provide data on periodicity of attack and insect species involved. Rearings will be carried out in the field and laboratory to obtain information on life history, and parasite control measures will be developed.

Accomplishments: The study has been initiated.

Assignment: J. L. Bean and R. N. Renlund, Entomologists.

8-27. Controlled Pollination of White Spruce. 154.0, 112.0. Picea glauca, P. mariana, P. omorika, P. rubens.

Object: To determine (1) the most effective bag types for pollination, (2) the developmental stage at which the female strobili show optimum receptivity, and (3) species- and self-compatibility.

Methods: (1) Tested were kraft, sausage casing, polyethylene, and cloth pollination bags alone and in combinations. (2) Bagged white spruce flowers were pollinated 6 times at 2-day intervals beginning at time of pollen shedding. (3) *Picea glauca*, *P. mariana*, *P. omorika*, and *P. rubens* were control-pollinated with pollen of each other and with pollen of *P. koyamai*, *P. orientalis*, *P. asperata*, *P. montigena*, *P. pungens*, *P. maximowiczi*, *P. retroflexa*, *P. jezoensis*, and *P. sitchensis*.

Accomplishments: (1) The combination of sausage casing and kraft bag has been accepted as most desirable. (2) White spruce female flowers are receptive over a period of 3 to 5 days (See Nienstaedt, Hans. 1958. Receptivity of female strobili of white spruce. Forest Sci. 4: 110-115, illus.). (3) None of the interspecific crosses gave good results; selfing studies have not yet been made.

Cooperators: Morton Arboretum; Morris Arboretum; Highland Park Herbarium (Rochester, N.Y.).

Assignment: Hans Nienstaedt, Geneticist.

9. University of Michigan, School of Natural Resources

Ann Arbor, Michigan

9-1. European Larch Seed Source. 111.1. *Larix decidua*.

Object: To test the suitability of various origins of European larch for growth in Lower Michigan.

Methods: Seeds of known origin were sown in the nursery, and stock will be set out in field plantations.

Accomplishments: The first phase of the experiment was outplanted. The second will be planted out in 1960.

Assignment: Stephen H. Spurr, Professor; Frank Murray, Forest Manager.

9-2. Regional Jack Pine Seed Source Study. 111.1. *Pinus banksiana*.

Object: (See study 8-9 for details.)

Accomplishments: Five-year measurements were completed and analyzed.

Cooperators: Lake States Forest Experiment Station. (See study 8-9 for others.)

Assignment: Stephen H. Spurr, Professor; Robert Zahner. Graduate Student.

9-3. Natural Variation in Aspens. 211.0. *Populus tremuloides*, *P. grandidentata*.

Object: To define the extent of natural variation in the two native aspens, to select superior aspen clones, and to develop methods of propagation for the establishment of such clones in plantations.

Methods: Field studies of natural variation, vegetative propagation, basic physiological studies, and outplantings of selected aspen clones have been made.

Accomplishments: A doctoral dissertation was completed in June 1959 by Burton V. Barnes on natural variation of two aspen species in northern Lower Michigan.

Assignment: Stephen H. Spurr, Professor; and Robert E. Farmer and Robert Koenig, Graduate Students.

10. University of Minnesota:
School of Forestry, Department of Plant Pathology and Botany, Department of Entomology and Economic Zoology, and North Central School of Agriculture (Grand Rapids, Minn.)
St. Paul Campus, St. Paul 1, Minnesota

10-1. Optimum Plot Size for Progeny Testing Red Pine. 11, 153. Pinus resinosa.

Object: To supply information concerning the optimum plot size needed for progeny-testing red pine.

Methods: Two thousand 9-year-old red pine within a single plantation were measured and mapped. The trees were then grouped into plots of various sizes: 4, 9, 16, and 25 trees per plot. The frequency distributions of mean diameter and height for the various plot sizes were tested for relative efficiency and normality.

Accomplishments: Results were published as a Master's thesis in April 1959.

Assignment: George M. Blake, Graduate Student.

10-2. Natural Hybridization of Minnesota Tree Species. 111, 211. General.

Object: To determine occurrence and frequency of natural interspecific hybridization among Minnesota tree species.

Methods: Field observations are made.

Accomplishments: One natural hybrid of black x white spruce has been reported. Although occurrence of hybrids involving quaking and bigtooth aspen has been predicted, none have yet been located within the state.

Pauley, Scott S. 1956. Natural hybridization of the aspens. Univ. of Minn. Forestry Notes, No. 47.

Little, Elbert L., Jr., and Pauley, S. S. 1958. A natural hybrid between black and white spruce in Minnesota. Amer. Midland Nat. 60(1): 202-211.

Cooperators: Minnesota Conservation Department; U. S. Forest Service.

Assignment: S. S. Pauley, Professor.

10-3. Tree Improvement Arboretum. 111, 211. General.

Object: To provide an initial screening test for adaptability of potentially useful ecotypes and hybrids of native and exotic trees in the Grand Rapids, Minn., area, and to insure their availability for future use.

Methods: Unreplicated 4- to 8-tree plots are planted at wide spacing. Records of survival and general adaptability are maintained.

Accomplishments: Initial plantings during the period 1956-58 have consisted of hardwoods, chiefly Populus (80 clonal lines and several seed sources of 20 species or hybrid combinations) and Betula (110 seed sources of five species or hybrid combinations). Underplanting of the hardwoods with conifer accessions is planned.

Cooperators: Blandin Paper Co.

Assignment: Scott S. Pauley, Professor.

10-4. Preliminary Minnesota Forest Genetics Survey. 111. Pinus banksiana.

Object: To locate trees and stands with unusual characteristics of possible usefulness in the University of Minnesota's tree improvement program. Major emphasis was placed on jack pine, but individual trees and stands of other species displaying characters of potential genetic interest were also noted.

Methods: Since limitations of time prevented a complete survey of the entire distribution of jack pine in Minnesota by observation at first hand, federal, state, and industrial foresters and others working in or otherwise well acquainted with the areas visited were interviewed. Whenever possible, the stands recommended by the field workers were visited for observation. Approximately 100 individual trees and stands (three-fourths of which were jack pine) with characteristics of genetic interest were located and described. Photographs, as well as maps with the stand locations, supplement a detailed report of this preliminary survey on file in the School of Forestry.

Accomplishments: A clinal change was found in the serotinous cone character in jack pine from predominantly closed-cone types in the northeast to open-cone types in the southern part of the range in Minnesota. Major variations were also observed in other cone characteristics, branching habit, stem and crown form, apparent vigor, and apparent disease and insect resistance. A previously unreported outlier stand of jack pine in southeastern Minnesota was located during this survey. These and other results of the survey have been reported in the following two publications:

Rudolph, T. D., Libby, W. J., and Pauley, S. S. 1957. Jack pine variation and distribution in Minnesota. Univ. of Minn. Forestry Notes, No. 58, 2 pp., illus.

_______. 1957. Geographic distribution of jack pine, *Pinus banksiana*, in Minnesota and some observations on genetic variations. Proc. Minn. Acad. Sci., illus. (In press.)

Assignment: Thomas D. Rudolph, and William J. Libby, Graduate Students.

10-5. Regional Jack Pine Seed Source Study in the Lake States. 111.1. *Pinus banksiana*.

Object and Methods: (See study 8-9 for details.)

Accomplishments: A fifth-year examination has been made to determine survival, total height, and important causes of injury. In addition four Minnesota plantings have been examined annually; causes of mortality and presence of insects and disease have been noted on trees occupying the center 16 positions on each plot. Data from these surveys are being analyzed.

Cooperators: Lake States Forest Experiment Station, and Minnesota Conservation Department Division of Forestry.

Assignment: T. Schantz-Hansen and A. C. Hodson, Professors; D. W. French, Associate Professor; R. A. Jensen, Assistant Scientist.

10-6. A Study of the Effect of the Source of Seed and the Influence of Insects Upon the Growth, Development, and Morphological and Physiological Characteristics of Jack Pine. 111.1, 111.3, 141, 152.0. *Pinus banksiana*.

Object: (1) To study the effect of climatic conditions upon the growth, development, and hardiness of jack pine from various locations in its range, (2) to study the effect of the form of the parent tree upon the form of the progeny, (3) to study the variations in seed value from different areas of the jack pine range, (4) to determine if the characteristic of cones opening annually on certain trees is inherited, and (5) to study the influence of diseases and insects upon the form and development of the tree.

Methods: In 1938 and 1939 cone collections were obtained from 139 sources of jack pine representing 25 localities throughout its range. These sources represent trees of good form and poor form, trees with nonserotinous cones, trees from good stands or poor stands, and trees from unclassified stands. Stock was grown in the nursery at the Cloquet Forest Research Center and planted out in 1942 and 1943. Each plot represented a single source and consisted of 25 trees with a 5- by 5-foot spacing. Records are kept for each tree. Surveys are made annually to determine mortality and incidence of insects and diseases. Total heights were measured annually through 1950 and again in 1955. In 1947 an additional planting was made to determine if the density of the stand influenced the incidence of insect attack; spacings (in feet) were: 1 by 1, 2 by 2, 3 by 3, 4 by 4, and 6 by 6.

Accomplishments: (1) Differences in tree form indicate the existence of geographic races of jack pine with distinct growth habits. (2) Plantings of far northern origin are slower growing than those of more southern origin. (3) Trees grown from seed collected in Lower Michigan suffered severe winter injury during the winter of 1947-48. (4) Insects causing major damage to the planting are shoot borer (Eucosma sonomana) and the pitch nodule maker (Petrova albicapitana). (5) Cone examination of each of 23 selected sources showed that closed-cone trees appeared most frequently in sources from northeastern Minnesota and adjacent parts of Ontario and Manitoba, northern Michigan, and much of Canada. Open-cone trees appeared with highest frequency in sources from Lower Michigan, southern and western Minnesota, New Brunswick, and Maine. Progenies of open-pollinated, closed-cone mother trees showed an overall cone-type ratio of 5 closed: 1 open: 2 mixed. Progenies derived from open-pollinated, open-cone mother trees showed an overall cone-type ratio of 1 closed: 2 open: 1 mixed. Results have been published in:

Schantz-Hansen, T., and Jensen, R. A. 1952. The effect of source of seed on growth of jack pine. Jour. Forestry 50: 539-544.

Schoenike, R. E., Rudolph, T. D., and Schantz-Hansen, T. 1959. Cone characteristics in a jack pine seed source plantation. Univ. of Minn. Forestry Notes, No. 76, 2 pp., illus.

Rudolph, T. D., Schoenike, R. E., and Schantz-Hansen, T. 1959. Results of one-parent progeny tests relating to the inheritance of open- and closed-cones in jack pine. Univ. of Minn. Forestry Notes, No. 78, 2 pp.

Assignment: T. Schantz-Hansen and A. C. Hodson, Professors; D. W. French, Associate Professor; and R. A. Jensen, Assistant Scientist.

10-7. Natural Variation in Jack Pine. 111.1. Pinus banksiana.

Object: To assess the extent and degree of natural variation in jack pine throughout the natural range of the species.

Methods: Field collections and studies of natural stands are made throughout the accessible parts of the species' range.

Accomplishments: The eastern half of the jack pine range was covered in 1958; sampling of the remaining portion will be completed in autumn 1959.

Assignment: Roland E. Schoenike, Graduate Student.

10-8. Lammas Growth and Prolepsis in Jack Pine. 111.1, 111.3, 151.0, 151.3. Pinus banksiana.

Object: To determine the characteristics of lammas growth and prolepsis in jack pine, the variation in frequency of occurrence of these phenomena over the range of the species in the Lake States, their effects on height and diameter growth and tree form, and possible factors influencing their occurrence in certain areas and in individual trees.

Methods: Growth periodicity and total height growth of 300 trees with various height growth habits are being studied by taking weekly height growth measurements in plantings with seed origins representing the distribution of jack pine in the Lake States. Racial and individual tree variation in incidence of lammas growth and prolepsis in these sources growing at six different locations and in four natural stands will be determined from individual tree observations made over three successive growing seasons.

The effect of an extended photoperiod on the incidence of these phenomena is being observed in two 96-tree plots of 4-year-old trees at the North Central School and Experiment Station at Grand Rapids. One plot is illuminated to simulate the longer daylength prevailing at 58° N. latitude; the other is to serve as a control. Within-plot comparisons of weekly growth measurements on trees with and without lammas growth and prolepsis will be made.

Differences in the anatomy and morphology of buds and stem tissues between trees with lammas growth and prolepsis and those with normal growth will be studied microscopically in sections cut from samples taken, in the winter condition, from trees with the various types of growth. The relation of lammas growth and prolepsis to diameter growth and possible false ring formation will be microscopically studied on the same material.

Accomplishments: The study was initiated at the School of Forestry, University of Minnesota, in the summer of 1957 and phases now under way will be completed in 1960. Early in 1959 the base of operations for the study was changed to the Northern Institute of Forest Genetics at Rhinelander, Wis., as the result of a cooperative agreement with the Lake States Forest Experiment Station. Preliminary results indicate variation between seed sources in the incidence of lammas growth and prolepsis.

Cooperators: Lake States Forest Experiment Station.

Assignment: Thomas D. Rudolph, Graduate Student.

10-9. Spruce Seed Source Tests. 111.1. *Picea* spp.

Object: To test seed sources of native and exotic spruce species for adaptability in north-central Minnesota.

Methods: Replicated outplantings are established from stock of known source. Mortality, susceptibility to disease and insects, growth, wood properties, and other characteristics are studied.

Accomplishments: One collection of 25 sources, chiefly white spruce of Canadian and Lake States origins, has thus far been outplanted.

Cooperators: Blandin Paper Co.; Petawawa Forest Experiment Station; Lake States Forest Experiment Station; Minnesota Conservation Department.

Assignment: Scott S. Pauley, Professor.

10-10. Seed Source Tests in Blue Spruce. 111.1. *Picea pungens*.

Object: To determine if there is geographic variation in resistance to damage by *Cytospora* canker, in resistance to winter injury, in drought resistance, and in foliage color. (See also study 8-5.)

Methods: Fifteen sources of blue spruce from Arizona, Colorado, Utah, Wyoming, and one unknown origin, have been assembled. Field trials are being made in Minnesota near Cook, Rosemount, Austin, Waseca, Crookston, Collegeville, and Morris. A latin-square design is being used in the field plantings.

Accomplishments: Plantations have been established at Cook and Rosemount. Other stock is awaiting field planting in transplant beds at Cloquet. One report has been published:

Duncan, Donald P. 1953. Poplar, elm, and Colorado spruce investigations at the University of Minnesota. *In* Lake States Forest Genetics Conf. Proc., Lake States Forest Expt. Sta. Misc. Rpt. 22: 18-20.

Cooperators: University of Minnesota, Branch Experiment Stations; Jayson Properties, Austin, Minn.; Lake States Forest Experiment Station; St. John's College, Collegeville, Minn.; E. C. Moran, Stanford, Mont.; Pete Trygg, Cook, Minn.

Assignment: D. P. Duncan, Associate Professor.

10-11. An Analysis of the Slash Pine Progeny Tests of the Ida Cason Callaway Foundation. 111.3, 14, 153. *Pinus elliottii*.

Object: To determine (1) differences in growth, form and disease resistance among open and controlled pollinated progeny of slash pine, (2) if parent-progeny correlations exist for certain characters of form and growth, (3) if current progeny-test designs are adequate.

Methods: Data have been collected from progeny-test plantations up to 6 years of age.

Accomplishments: Data are being analyzed.

Cooperators: Southeastern Forest Experiment Station; Ida Cason Callaway Foundation.

Assignment: John C. Barber, Graduate Student.

10-12. Studies on the Resistance of Jack Pine to the Endemic Rusts of Minnesota. 111.3, 151.5. *Pinus banksiana*.

Object: (1) To gain information on the nature of resistance of jack pine to rust fungi. (2) To test the disease reaction of putatively resistant trees.

Methods: Rust-free trees are selected in stands which have a high incidence of the disease. Scions from these trees are grafted onto jack pine understock. When the grafts are 2 to 3 years old they will be artificially inoculated.

Accomplishments: The 1958 grafts will be inoculated in the summer and fall of 1959. One report has been prepared:

Anderson, Neil A. (In press.) Stalactiform canker on Minnesota jack pine. Forest Sci.

Cooperators: Lake States Forest Experiment Station.

Assignment: Neil A. Anderson, Plant Pathologist; and David W. French, Associate Professor.

10-13. The Inheritance of Tracheid Length and Specific Gravity in Slash Pine. 141, 142. *Pinus elliottii*.

Object: To determine mode of inheritance and heritability of tracheid length and specific gravity in slash pine.

Methods: The parents and progeny of controlled crosses will be analyzed.

Accomplishments: Selected parents located at the University of Georgia have been selfed and reciprocally crossed. To date over 95 possible combinations have been completed.

Cooperators: University of Georgia, Forestry School.

Assignment: James T. Greene, Graduate Student.

10-14. Spruce Grafting. 151.02. *Picea* spp.

Object: To develop (1) a suitable nursery method of grafting spruce scions from old trees for clonal line propagation, and (2) a method of grafting seedlings and transplants into the tops of old trees.

Methods and Accomplishments: Dormant and succulent tissue grafts have been made.

Cooperators: Blandin Paper Co.

Assignment: William H. Cromell, Instructor (North Central School of Agriculture).

10-15. Growth of Northern Conifers Under Long Photoperiods in the South. 151.04, 154.2. *Picea glauca*, *P. mariana*, *Pinus resinosa*, *P. strobus*.

Object, Methods, and Accomplishments: (See study 8-22.)

Cooperators: Lake States Forest Experiment Station; Southeastern Forest Experiment Station; Wisconsin Conservation Department.

Assignment: Richard F. Watt, Graduate Student.

10-16. Initiation of Ovulate Strobili Primordia in Red Pine. 151.31. *Pinus resinosa*.

Object: To determine the time of ovulate strobili primordia formation in red pine.

Methods: Buds presumed to contain strobili primordia are collected at weekly intervals during the growing season, fixed, embedded in paraffin, sectioned, stained, and examined. The collections being used cover six growing seasons.

Accomplishments: Samples of 1955 and 1956 collections have been studied. By mid-August ovulate strobili are easily recognized. Staminate strobili are formed much earlier and are recognizable by late July. The ovulate strobili appear to continue growth throughout the winter months.

Cooperators: Lake States Forest Experiment Station; University of Wisconsin; Wisconsin Conservation Department.

Assignment: Robert G. Hitt, Graduate Student.

10-17. Vacuum Storage of Pollen. 154.02. *Picea abies*, *P. glauca*, *Pinus banksiana*.

Object, Methods, and Accomplishments: (See study 6-1 for details.)

Cooperators: U. S. Agricultural Research Service, Plant Pest Control Branch.

Assignment: John C. Barber and Roland E. Schoenike, Graduate Students.

10-18. Variation of the Photoperiodic Response in Paper Birch Seed Sources. 211, 251.04. *Betula papyrifera*.

Object: To assess the extent and degree of natural variation of the photoperiodic response in paper birch throughout the natural range of the species.

Methods: Seed from natural stands of paper birch was collected from Canada and 22 states of the United States. Observations have been made on the paper birches growing under natural conditions in Minnesota and under the natural shorter day and frost-free conditions in Florida. Responses to artificial illumination and winter chilling requirements have also been investigated.

Accomplishments: The following report has been published:

Wang, Chi-Wu, and Perry, T. O. 1958. The ecotypic variation of dormancy, chilling requirements and photoperiodic response in *Betula* species. Tenth Internatl. Cong. Genet. Proc. 2: 307.

Cooperators: University of Florida, School of Forestry; Blandin Paper Co.

Assignment: Chi-Wu Wang, Research Associate.

10-19. The Natural Hybrid of Paper Birch and Bog Birch in Minnesota. 211.0, 212.01, 243. *Betula papyrifera*, *B. pumila*.

Object: To study the natural hybrid of paper birch and bog birch with regard to distribution, morphological characteristics and their mode of inheritance, and cytology.

Methods: A survey of hybrid habitats has been conducted with specimens collected. Morphological characteristics of the hybrid are studied and compared with those of the parental species. Hybrid index will be used. Cytological investigations will include determination of chromosome numbers and study of the meiotic behavior of the hybrid.

Accomplishments: About 200 individual hybrids have been located in Minnesota. Most of these occurred in the transition zone between the wet part of bogs and the drier land surrounding the bogs. Preliminary studies indicate that several morphological characteristics are quantitatively inherited. Certain hybrid individuals appear to be the results of backcrossing. The hybrids display a high degree of infertility, and a large proportion of the pollen grains are defective. This study will be continued and will be concerned mainly with material from a selected hybrid swarm. Emphasis will be placed on hybrid index, mode of inheritance of characters, and cytological studies. A Master of Science thesis has been completed: The natural hybrid of paper birch and bog birch in Minnesota. University of Minnesota, January 1959.

Assignment: Knud E. Clausen, Graduate Student.

10-20. Toxin in Relation to Resistance to Dutch Elm Disease. 211.3, 251.5. *Ulmus americana*.

Object: To devise a method of mass-screening young seedlings of American elm to select those that are resistant to Dutch elm disease.

Methods: Toxin produced by fungus cultures has been used as a screening agent.

Accomplishments: There was found a differential growth response of susceptible American and resistant Siberian elm to toxin filtrates. One report has been published:

Santamour, Frank S., and French, David W. 1958. Toxin in relation to resistance to Dutch elm disease. Univ. of Minn. Forestry Notes, No. 65, 2 pp.

Assignment: Frank S. Santamour, Jr., Graduate Student; David W. French, Associate Professor.

10-21. Sex-Associated Characteristics in the Aspens and Juvenile Sex Determination. 211.3, 251.3. *Populus tremuloides, P. grandidentata*.

Object: To study characteristics associated with sex in aspen as a means of determining sex in immature plants.

Methods: Morphological and physiological characteristics of wild native aspen clones of known sex are studied to determine if any characteristics show a biologically significant correlation with sex.

Accomplishments: Work on this project has just begun.

Assignment: George M. Blake, Graduate Student.

10-22. Tests of *Populus* Materials for Minnesota Uses. 211.3, 221. *Populus* spp.

Object: To discover poplar selections capable of good survival and growth under Minnesota conditions, and suitable for timber, pulpwood, windbreaks and shelterbelts, or for ornamental purposes.

Methods: In 1947 and 1948 about 150 clones of cottonwoods and balsam poplars (or hybrids of species within or between these sections of the genus) were collected from numerous sources and planted at Rochester, Minn., on a very favorable bottomland site. Further testing of some of the more promising selections has been undertaken at the Rosemount Agricultural Experiment Station and elsewhere in the State.

Accomplishments: Ten selections appear to be most promising among those tested at Rochester and are being further tested in plantings elsewhere. These include three selections of *P. deltoides*, one of *P. nigra*, five hybrids, and a selection from a Minnesota plantation of unknown parentage. Data on disease and insect resistance, winter hardiness, form, and growth have been recorded for all selections.

Duncan, D. P. 1953. Poplar, elm, and Colorado spruce investigations at the University of Minnesota. *In* Lake States Forest Genet. Conf. Proc., Lake States Forest Expt. Sta. Misc. Rpt. 22: 18-20.

_______, Kaufert, F. H., and French, D. W. 1955. Selected poplars for Minnesota plantings. Univ. of Minn. Forestry Notes, No. 43, 2 pp., illus.

Cooperators: Mayo Institute of Experimental Medicine; University of Minnesota Division of Extension, and Rosemount Agricultural Experiment Station.

Assignment: F. H. Kaufert, Director; and D. P. Duncan, Associate Professor.

10-23. Sexuality in Quaking Aspen. 211.3, 241, 242, 251.3. *Populus tremuloides*.

Object: To determine the ratio of males to females in wild populations, the frequency of hermaphroditism, the modes of inheritance of sex, and related phenomena.

Methods: Native wild clones, seedling populations, and progenies derived from controlled pollinations are studied.

Accomplishments: Native populations of quaking aspen are typically composed of more males than females, the ratio being about 3:1. Hermaphroditism is a characteristic phenomenon in such populations but is more frequent in predominantly female trees (about 20 percent) than in predominantly male trees (about 4 percent). Hermaphroditic trees are apparently self fertile.

Pauley, Scott S., and Mennel, George F. 1957. Sex ratio and hermaphroditism in a natural population of quaking aspen. Univ. of Minn. Forestry Notes, No. 55, 2pp., illus.

Assignment: Scott S. Pauley, Professor; and S. C. Hong, Graduate Student.

10-24. The Relation Between Anatomy and Inherent Growth Potential of Hybrid Poplars. 212.0, 251.3. *Populus* spp.

Object: To correlate certain characteristics of stem and root anatomy of young hybrid poplars with their growth in height and diameter, and to explore the possibility of using such correlations as criteria for early selection for growth vigor.

Methods: Size and proportion of various cell types were determined in stems and roots of 1-year-old trees (from cuttings). Height and diameter of the same clones were measured in test plantations.

Accomplishments: The data are being analyzed.

Cooperators: Northeastern Forest Experiment Station.

Assignment: Frank S. Santamour, Jr., Graduate Student.

10-25. Hybridization and Grafting of Elm. 212.01, 251.02. *Ulmus* spp.

Object: To develop satisfactory techniques for the hybridization and grafting of elm species in the greenhouse and field.

Methods: Hybrids have been developed in the greenhouse by forcing flower-bud bearing branches in water (or by bottle-grafting) under different temperature and relative humidity conditions; field hybrids have been developed by the use of various controlled pollination methods; vegetative propagation has been done by layering and grafting.

Accomplishments: Greenhouse temperature and humidity are critical factors in hybridization. Corn pollination bags have proved best for controlled pollinations in the field. Bottle grafts give fair success in the greenhouse, but fruit loss before maturity is high in some species. Layering trials have been unsuccessful.

Cooperators: South Dakota State College.

Assignment: Paul E. Collins, Graduate Student.

10-26. Mode of Inheritance Studies in *Populus*. 241, 251.04. *Populus tremula*, *P. tremuloides*, *P. trichocarpa*.

Object: Through analysis of F_2 and backcross progenies to determine the mode of inheritance of various morphological and physiological characteristics.

Methods: F_2 and backcross progenies, involving European and American aspens and northern and southern sources of black cottonwood, are produced by controlled pollination and outplanted for study.

Accomplishments: Four F_2 and two backcross progenies have thus far been produced and outplanted. First-year growth cessation records on F_2 segregates of a North-South *P. trichocarpa* cross suggest polygenic inheritance of the photoperiodic response.

Cooperators: Blandin Paper Co.

Assignment: Scott S. Pauley, Professor.

10-27. Vegetative Propagation of Basswood, Red Elm, and Hackberry. 251.02. *Celtis occidentalis*, *Tilia americana*, *Ulmus rubra*.

Object: To determine a suitable method of propagating clonal lines from selected individuals.

Methods: Dormant and active stem cuttings and root cuttings are treated with auxins in a sand medium and watered by an automatic misting system. Air-layering is also being tested.

Accomplishments: Dormant stem cuttings of basswood have proved exceedingly resistant to rooting. Work is now in progress with other species.

Assignment: George M. Blake, and Donald Peterson, Graduate Students.

10-28. Field Grafting of Aspen. 251.02. *Populus tremuloides*.

Object: To determine the feasibility of introducing improved clonal lines in natural aspen stands of low quality.

Methods: Selected clones are cleft- or whip-grafted on native suckers in spring or bud-grafted in summer. All tests are located on Diamond Match Co. lands in the vicinity of Orr, Minn.

Accomplishments: Budding trials conducted in August 1958 have indicated that a higher percentage of take may be expected by budding at an earlier date (June 20 to August 1) and by utilizing rootstocks (suckers) in their first or second season of growth. Spring grafting trials with dormant scions have resulted in a high percentage of take.

Cooperators: Diamond Match Co.

Assignment: Scott S. Pauley, Professor.

10-29. Seed Dormancy in American Basswood. 251.3. *Tilia americana*.

Object: To determine when the germination inhibitor develops during seed development and find a means of breaking seed dormancy.

Methods: Developing seeds are studied under the microscope; embryos are cultured and germination tests are made of treated seeds.

Accomplishments: The following report has been prepared:

Peters, William J. 1959. Histogenesis of *Tilia americana* embryos. Minn. Acad. Sci. (In press.)

Assignment: William J. Peters, Graduate Student.

10-30. Aspen Propagation from Seed. 254.2. *Populus grandidentata*, *P. tremuloides*.

Object: To determine a satisfactory method of propagating quaking and bigtooth aspen from seed.

Methods: Aspen seed is sown in the greenhouse and in outdoor beds and grown under various cultural conditions, including variation in soil mixture, fumigation, and fungicide treatments.

Accomplishments: Quaking and bigtooth aspen seeds were sown in the nursery and the greenhouse in the spring of 1959. Some treatments promise reasonable success. Quaking aspen wildings have been transplanted successfully.

Assignment: James T. Greene, Graduate Assistant.

11. University of Wisconsin, Departments of Genetics and Plant Pathology
Madison 6, Wisconsin

11-1. Selection and Testing of Superior Trees. 111.0, 211.0. General.

Object: To select and field-test individual forest trees in an effort to determine their genetic quality.

Methods: Individual trees have been selected and vegetatively propagated, and their progeny (both open-pollinated and, whenever possible, control-pollinated) put under field tests.

Accomplishments: Over 375 individual tree selections have been made. Included are both plus trees and variants with some characteristics that may be genetically controlled and could thus be a useful marker in future breeding work. Open-pollinated progeny from most of these trees are under field test in two or more places in Wisconsin.

Cooperators: Wisconsin Conservation Department; Nekoosa-Edwards Paper Co.; and several county forestry boards.

Assignment: R. G. Hitt, Assistant Professor; and R. R. Hartig, Project Assistant.

11-2. Provenience Studies With Red Pine and Several Other Pine Species. 111.1. *Pinus resinosa*, *P.* spp.

Object: To determine the genetic variation within the various species, to recognize possible races, and to identify potential seed sources from other areas which might be desirable for use in Wisconsin reforestation.

Methods: Individual tree and area collections of open-pollinated seed of various species have been brought together and put under field test in a number of areas throughout the State.

Accomplishments: All trials are too young as yet to be of much value in predicting or evaluating the merits of sources from particular areas.

Cooperators: Nekoosa-Edwards Paper Co.; Wisconsin Conservation Department; and various county forestry committees.

Assignment: R. G. Hitt, Assistant Professor; and R. R. Hartig, Project Assistant.

11-3. Red Cedars Resistant to Cedar-Apple Rust. 111.3, 151.5. *Juniperus virginiana.*

Object: To secure red cedars suitable for game cover and forest plantations, especially in southwestern Wisconsin, which can be planted without interfering with nearby apple orchards.

Methods: Selections have been made on southwestern Wisconsin hillsides in wet weather when the spore horns were conspicuous. Selected trees have been propagated vegetatively. Likewise, a collection of ornamental upright red cedars have been secured. Various selections have been set out in replicated plantings in the University of Wisconsin Arboretum. Likewise, open-pollinated seedlings from resistant trees have been grown at the Griffith State Nursery and at Boscobel.

Accomplishments: A small number of selections appear very promising, and material is available for further breeding work. The project is at present on a standby basis.

Cooperators: Wisconsin Conservation Department; McKay Nursery Company; Hill Nursery Company.

Assignment: A. J. Riker, Professor.

11-4. Self-Compatibility Tests on Red Pine. 112.03, 154.0. *Pinus resinosa.*

Object: To determine the extent to which the pollen of a given red pine tree is functional on the pistillate cones of the same individual, the effects of self-pollination, and the possible value of inbreds in forest tree breeding.

Methods: A program of controlled pollination using individual red pine trees has been undertaken. Both self-pollinations and cross-pollinations have been undertaken to serve as checks on techniques, timing, pollen viability, etc.

Accomplishments: Data and material from 3 years of pollinations are being studied and field tested.

Cooperators: Lake States Forest Experiment Station.

Assignment: R. G. Hitt, Assistant Professor.

11-5. Verified Forest Tree Seed for Wisconsin. 122.0. *Pinus resinosa.*

Object: To produce seed of known origin from selected trees for use in reforestation until such time as artificial forest tree seed can be derived from progeny-tested clones.

Methods: Old-growth and good second-growth natural stands are chosen, improvement cuts are made to remove undesirable trees, and management for seed production is started.

Accomplishments: Three red pine areas have been selected and set aside, and seed has been collected. A beginning has been made on stand improvement. Work has been started on a fourth area dedicated to this use.

Cooperators: Wisconsin Conservation Department; Vilas County Forestry Committee.

Assignment: R. G. Hitt, Assistant Professor; R. R. Hartig, Project Assistant.

11-6. Establishment of Forest Tree Seed Orchards. 122.1. General.

Object: To establish a system of forest tree seed orchards for producing seed of improved genetic quality.

Methods: Both greenhouse and field grafts of selected stock are at wide spacings (16 by 16 and 20 by 20 feet) on a number of sites in central and southern Wisconsin.

Accomplishments: Several "pilot orchards" have been established for research on management methods.

Cooperators: Wisconsin Conservation Department; Nekoosa-Edwards Paper Co.; Juneau County Forestry Board.

Assignment: R. G. Hitt, Assistant Professor; R. R. Hartig, Project Assistant.

11-7. Investigations on Seedcoat Color in Austrian Pine. 141,111.3. Pinus nigra.

Object: To study the method of inheritance of seedcoat color in Austrian pine for possible use later as a genetic marker in controlled pollination work.

Methods: Various crosses involving different mother trees which bear different seedcoat color types have been made.

Accomplishments: Results are interesting, but data are insufficient to draw any definite conclusions. Further crosses will be made.

Cooperators: Wisconsin Conservation Department.

Assignment: R. G. Hitt, Assistant Professor; R. R. Hartig, Project Assistant.

11-8. Flowering Stimulation and Induction Trials. 151.01. Pinus resinosa.

Object: To stimulate flowering on already flowering trees and to induce reproductive growth on trees having largely vegetative growth.

Methods: Various methods, largely mechanical to date, have been used. These include root pruning, strangulation, girdling, and defoliation.

Accomplishments: The root pruning, strangulation, and girdling have produced some flowering responses. The greatest increase was in male flower production. Age difference plays an important role in both application and duration of certain treatment types.

Cooperators: Wisconsin Conservation Department; Nekoosa-Edwards Paper Co.

Assignment: R. G. Hitt, Assistant Professor; R. R. Hartig, Project Assistant.

11-9. Flowering on Red Pine as Influenced by Phloem Inversions. 151.01. Pinus resinosa.

Object: To determine the effectiveness of phloem inversions in increasing the rate of flowering in red pine.

Methods: A small band of phloem tissue was cut from the tree, inverted, and replaced. This is reported to cause flowering or stimulate it in certain horticultural crops.

Accomplishments: The biggest problem was to find the best time of the year in which to make the inversions. No conclusive results are available yet.

Cooperators: Wisconsin Conservation Department; Nekoosa-Edwards Paper Co.

Assignment: R. R. Hartig, Project Assistant.

11-10. Vegetative Propagation of Red Pine. 151.02. Pinus resinosa.

Object: To test various methods of vegetative propagation of red pine in an effort to find an inexpensive and effective method for use, particularly in the propagation of selected lines.

Methods: Tested have been greenhouse grafting, air-layering, rooting of cuttings, bottle grafting, field grafting, and succulent scion grafting.

Accomplishments: Percent survival of greenhouse grafts has risen, and the technique is fairly well refined. Field grafting techniques have given a high rate of survival. Cuttings have rooted so poorly as to be of no real significance. Air-layering generally was put on too late, hence there has been little or no root formation even though callus formation was excellent.

Cooperators: Wisconsin Conservation Department; Nekoosa-Edwards Paper Co.

Assignment: R. G. Hitt, Assistant Professor; R. R. Hartig, Project Assistant.

11-11. Methods for Scion-Wood Production. 151.02. Pinus resinosa.

Object: To determine the best method as well as the best time of the year to apply treatments for use in scion-wood production within selected clones.

Methods: Branch tips on terminals as well as on lateral branches of red pine (8 to 12 years old) were clipped off at various time intervals during the summer in an effort to stimulate latent bud and subsequent shoot development.

Accomplishments: Tips removed under northeast Wisconsin conditions prior to mid-July produced scions over 3 inches long by the end of the growing season. These were long enough for use in grafting.

Cooperators: Wisconsin Conservation Department; Nekoosa-Edwards Paper Co.

Assignment: R. R. Hartig, Project Assistant; R. G. Hitt, Assistant Professor.

11-12. Microsporogenesis in Red Pine. 151.31. Pinus resinosa.

Object: To work out for Wisconsin conditions the developmental pattern of pollen formation in red pine.

Methods: Buds containing microsporangia or primordia thereof are collected at regular intervals and their development noted.

Accomplishments: Pilot studies indicate that the microsporangia are formed considerably (several weeks) earlier than are the ovulate strobili. Growth or development continues through the winter. The preliminary results indicate that the contents of the sporangium overwinter as sporogenous material--at least until early April.

Cooperators: Wisconsin Conservation Department.

Assignment: R. G. Hitt, Assistant Professor.

11-13. The Development of Blister-Rust-Resistant Eastern White Pine. 151.5, 111.3, 112.0, 122.1, 151.02. Pinus strobus.

Object: To develop white pine trees of superior quality and resistant to blister rust, for use in extensive reforestation programs in the Lake States and elsewhere as desirable.

Methods: (1) Trees apparently resistant to rust were selected in native stands severely infected with blister rust. (2) Resistance of selections has been tested by artificial inoculation of grafts; tests have been made of resistance of progenies of selections from natural and controlled pollinations; efficient methods have been developed for screening large populations of progenies for disease resistance by artificial inoculations. (3) Resistant materials have been used in controlled crosses; resistance transmissibility in selections has been determined; best combinations of selections have been made; resistant individuals have been selected among F_1 progenies with a view toward further breeding and intensification of factors governing resistance; hybridization has been made to a limited extent with certain related species offering promise of incorporation of additional factors for resistance. (4) Investigation has been made of the feasibility of establishing seed orchards as a source of seed for rust-resistant planting stock. (5) Methods have been investigated for successful vegetative propagation, especially of older trees, both by grafting and rooting cuttings; the growth and development of grafts and rooted cuttings has been studied in field outplantings.

Accomplishments: The program to develop blister-rust-resistant white pine trees was begun in 1937. Major accomplishments to date include the following: (1) That some native white pines are resistant to blister rust was demonstrated. (2) One common type of resistant reaction was the "corking-out" of blister rust lesions in stem bark tissues. (3) Of some 250 native white pines selected in Wisconsin and Minnesota for apparent resistance, about 60 have shown enough resistance to warrant further breeding work. (4) Facilities and techniques for testing resistance of progenies and selections were developed, including a permanent testing nursery near Wisconsin Rapids. (5) A breeding program, initiated to determine the pattern of inheritance, indicated that resistance is due to the additive effects of multiple genetic factors. (6) Hybrids with related resistant species were made and are now being tested. (7) Progeny tests with seedlings from both wind-pollinations and controlled crosses have revealed some selections which have a relatively high general combining ability for rust resistance. These are being used in the breeding program to find especially favorable combinations of resistant selections for possible use in seed orchards. (8) Selection and re-testing of F_1 seedlings from progenies of controlled crosses is continuing. (9) Important to the testing work was the demonstration that susceptibility to blister rust infection decreased as age of the trees increased. (10) Methods of propagation of resistant trees by grafting and rooting cuttings, in the greenhouse, nursery, and field, have been studied, and characteristics of growth of vegetatively propagated stock have been observed. (11) Induction of early flowering of seedlings by grafting in the crowns of large trees has been studied.

Cooperators: Lake States Forest Experiment Station; Quetico-Superior Wilderness Research Center; Nekoosa-Edwards Paper Co.

Assignment: R. F. Patton, Associate Professor; and A. J. Riker, Professor.

11-14. Poplar Improvement. 211.0, 212.0, 251.5. Populus spp.

Object: To discover, develop, and evaluate improved poplars for Wisconsin.

Methods: Selections and hybrids of several poplars were made or obtained from cooperators and tested in field plantations over the past 20 years. Artificial inoculations have been made to test the resistance of these poplars to certain pathogens.

Accomplishments: Of 750 poplar clones tested 30 have shown promising growth and disease resistance; native cottonwoods generally have done best. Rooted cuttings should be used for propagation. F_1 aspen hybrids show variable growth. There is clonal variation in rooting of aspen cuttings.

Cooperators: Wisconsin Conservation Department; U. S. Forest Service; Nekoosa-Edwards Paper Co.

Assignment: J. G. Berbee, Assistant Professor.

11-15. Oak Wilt: Its Development, Spread, and Control. 211.3, 251.02. Quercus spp.

Object: Within the important oak species, to find trees resistant to the oak wilt fungus; to devise effective methods for their propagation; to determine basic differences in disease development between the red and the white oak groups.

Methods: In the course of oak wilt investigations, scores of trees which have escaped natural infection have been inoculated artificially.

Accomplishments: So far, all red, black, or northern pin oaks have succumbed either to single or to repeated inoculations. A number of the infected bur oaks have shown foliage symptoms the year of infection, but not thereafter. Both morphological and physiological differences between these two groups are being studied. Elsewhere, attempts to propagate oaks vegetatively have given variable results.

Cooperators: Wisconsin Conservation Department; Nekoosa-Edwards Paper Co.

Assignment: J. E. Kuntz, Associate Professor; and A. J. Riker, Professor.

11-13. Maple Blight. Its Cause, Development, and Control. 211.3, 251.5. *Acer saccharum*.

Object: To search for symptomless sugar maple trees among severely blighted trees in known disease areas; if found, to preserve these individuals by vegetative propagation; and eventually, to test their resistance to the disease incitant once it is known.

Methods: Among the severely blighted sugar maple trees in the disease areas any trees free of disease symptoms will be carefully mapped, labeled, and preserved by vegetative propagation until they can be tested for possible resistance to the disease incitant.

Accomplishments: Many severely blighted areas in Wisconsin have been located. Trees showing all degrees of symptom development have been mapped and labeled, and pertinent data recorded. Disease progression has been studied within infected trees and through the blighted stands. Suspected causal agents are being investigated in an attempt to determine the primary disease incitant.

Cooperators: Wisconsin Conservation Department; Lake States Forest Experiment Station; maple-using industries.

Assignment: J. E. Kuntz, Associate Professor.

A Tabular Summary

A brief summary of the information contained in the project statements is included to show the number of studies devoted to each genus and subject-matter category. While it is recognized that any quantitative listing of projects ignores differences in size, cost, value, and quality of the various studies, the listing does help to show where current interests and activities are greatest. Conversely it can help point out areas where more emphasis should be placed.

The following tables show the present pattern of forest tree improvement work in the Lake States expressed in terms of numbers of projects. The tables do not cross check because many projects deal with more than one genus or species and many also include two or more subject-matter categories.

Table 1.--Projects by research agencies and genera

Genera	Research agencies1/											
	1	2	3	4	5	6	7	8	9	10	11	Total
Abies	..	..	..	..	1	..	..	..	..	..	..	1
Acer	..	..	..	..	..	..	..	..	..	..	1	1
Betula	..	..	..	..	..	..	..	..	..	2	..	2
Celtis	..	..	..	..	..	..	..	..	..	1	..	1
Fraxinus	..	..	..	..	..	..	1	..	..	..	..	1
Juniperus	..	..	..	..	..	..	..	..	..	..	1	1
Larix	..	1	2	..	..	..	..	1	1	..	..	5
Picea	1	..	1	2	..	1	..	11	..	5	..	21
Pinus	..	1	6	3	7	1	1	13	1	12	10	55
Populus	..	3	1	..	..	..	3	..	1	7	1	16
Quercus	..	..	..	..	..	..	..	..	..	..	1	1
Salix	..	..	1	..	..	..	..	..	..	..	..	1
Tilia	..	..	..	..	..	..	..	..	..	2	..	2
Tsuga	..	..	..	..	..	..	..	1	..	..	..	1
Ulmus	..	..	..	..	..	..	..	..	..	3	..	3
General	..	1	3	..	1	..	1	3	..	2	2	13
Total	1	6	14	5	9	2	6	29	3	34	16	125

1/ Numbers refer to research agencies as follows:

1. Consolidated Water Power & Paper Co.
2. The Institute of Paper Chemistry
3. Michigan State University
4. Nekoosa-Edwards Paper Co.
5. Quetico-Superior Wilderness Research Center
6. U. S. Agricultural Research Service
7. U. S. Forest Products Laboratory
8. U. S. Lake States Forest Experiment Station
9. University of Michigan
10. University of Minnesota
11. University of Wisconsin

Table 2A.--Projects by categories and genera (softwoods)

	Categories	Abies	Juniperus	Larix	Picea	Pinus	Tsuga	General	Total
11	Selection and testing of variation	..	..	..	..	1	..	..	1
111	Natural variation	..	..	1	..	1	..	2	4
111.0	Natural variation among species	..	..	..	1	..	..	5	6
111.1	Natural variation among races	..	..	4	11	19	1	..	35
111.2	" " " stands	..	..	..	..	1	..	..	1
111.3	" " " individuals	..	1	..	1	7	..	..	9
112.0	Induced variation by recombination	..	..	..	1	1	..	..	2
112.01	Interspecific hybridization	..	..	1	..	3	..	..	4
112.02	Intraspecific hybridization	..	..	..	..	1	..	..	1
112.03	Selfing	..	..	..	..	1	..	..	1
122	Seed production	..	..	..	1	..	..	1	2
122.0	Seed production areas	..	..	..	..	1	..	..	1
122.1	Seed orchards	..	..	..	..	3	..	1	4
14	Fundamental genetics studies	..	..	..	..	1	..	..	1
141	Mode of inheritance	..	..	..	..	3	..	..	3
142	Reaction range	..	..	..	..	1	..	..	1
151.0	Physiology	..	..	..	..	4	..	..	4
151.01	Flower induction	..	..	..	..	3	..	..	3
151.02	Vegetative propagation	1	..	..	2	8	..	1	12
151.03	Nutritional studies	..	..	..	..	1	..	..	1
151.04	Photoperiodism	..	..	..	3	2	..	..	5
151.05	Thermoperiodism	..	..	..	1	..	..	..	1
151.08	Phenology	..	..	..	1	..	..	..	1
151.3	Morphology and anatomy	..	..	..	..	2	..	..	2
151.31	Flower primordia	..	..	..	..	2	..	..	2
151.32	Wood characteristics	..	..	..	..	2	..	1	3
151.321	Wood density	..	..	..	..	1	..	..	1
151.5	Pathology	..	1	..	..	7	..	..	8
152.0	Entomology	..	..	..	..	2	..	1	3
153	Biometry	..	..	..	..	2	..	1	3
154.0	Controlled pollination	..	..	..	1	1	..	..	2
154.02	Pollen storage	..	..	..	2	2	..	..	4
154.2	Nursery techniques	..	..	..	2	2	..	..	4
	Total	1	2	6	27	85	1	13	135

Table 2B.--Projects by categories and genera (hardwoods)

	Categories	Acer	Betula	Celtis	Fraxinus	Populus	Quercus	Salix	Tilia	Ulmus	General	Total
211	Natural variation	..	1	..	..	1	..	..	..	..	1	3
211.0	Natural variation among species	..	1	..	..	2	..	..	..	..	1	4
211.3	Natural variation among individuals	1	..	..	..	4	1	..	..	1	..	7
212	Induced variation	..	..	..	..	1	..	..	..	..	..	1
212.0	Induced variation by recombination	..	..	..	..	3	..	..	..	..	..	3
212.01	Interspecific hybridization	..	1	..	..	1	..	1	..	1	..	4
221	Clonal lines	..	..	..	..	1	..	..	..	..	..	1
222	Seed production	..	..	..	..	..	..	..	..	..	1	1
241	Mode of inheritance	..	..	..	..	2	..	..	..	..	..	2
242	Reaction range	..	..	..	..	1	..	..	..	..	..	1
243	Experimental taxonomy	..	1	..	..	..	..	..	..	..	..	1
251.0	Physiology	..	..	..	..	1	..	..	..	..	..	1
251.02	Vegetative propagation	..	..	1	..	1	1	..	1	2	1	7
251.04	Photoperiodism	..	1	..	..	1	..	..	..	..	..	2
251.3	Morphology and anatomy	..	..	..	..	3	..	..	1	..	..	4
251.32	Wood characteristics	..	..	..	1	2	..	..	..	..	1	4
251.321	Wood density	..	..	..	..	1	..	..	..	..	..	1
251.325	Tension wood	..	..	..	..	1	..	..	..	..	..	1
251.4	Ecology	..	..	..	..	1	..	..	..	..	..	1
251.5	Pathology	1	..	..	..	1	..	..	..	1	..	3
254.2	Nursery techniques	..	..	..	..	1	..	..	..	..	..	1
	Total	2	5	1	1	29	2	1	2	5	5	53

Table 3A.--*Pinus* projects by research agencies and species

Research agencies	banksiana	contorta	monticola	nigra	resinosa	strobus	sylvestris	Other	Genus[1]	Total
2. Institute of Paper Chemistry	..	..	..	..	..	..	..	1	..	1
3. Michigan State University	..	..	..	2	2	1	1	1	1	8
4. Nekoosa-Edwards Paper Co.	2	..	..	..	1	..	..	..	..	3
5. Quetico-Superior Wilderness Research Center	..	..	..	..	3	6	..	1	..	10
6. U. S. Agricultural Research Service	1	..	..	..	..	..	..	..	..	1
7. U. S. Forest Products Laboratory	..	..	..	..	1	..	..	..	..	1
8. U. S. Lake States Forest Experiment Station	3	1	1	..	5	4	1	1	..	16
9. University of Michigan	1	..	..	..	..	..	..	..	..	1
10. University of Minnesota	7	..	..	..	3	1	..	2	..	13
11. University of Wisconsin	..	..	..	1	8	1	..	1	..	11
Total	14	1	1	3	23	13	2	7	1	65

[1] Applying to all pine species.

Table 3B.--*Picea* projects by research agencies and species

	Research agencies	*abies*	*glauca*	*mariana*	*pungens*	*rubens*	Other	Genus[1]	Total
1.	Consolidated Water Power & Paper Co.	..	1	..	..	..	..	..	1
3.	Michigan State University	..	1	..	..	..	..	..	1
4.	Nekoosa-Edwards Paper Co.	..	..	2	..	..	..	..	2
6.	U. S. Agricultural Research Service	1	1	..	..	..	..	..	2
8.	U. S. Lake States Forest Experiment Station	2	9	3	1	2	2	..	19
10.	University of Minnesota	1	2	1	1	..	..	2	7
	Total	4	14	6	2	2	2	2	32

[1] Applying to all spruce species.

Table 4A.--*Pinus* projects by categories and species

	Categories	*banksiana*	*contorta*	*monticola*	*nigra*	*resinosa*	*strobus*	*sylvestris*	Other	Genus[1]	Total
11	Selection and testing variation	..	..	..	..	1	..	..	..	..	1
111	Natural variation	1	..	..	..	..	..	..	..	..	1
111.1	Natural variation among races	9	..	..	1	4	3	2	3	..	22
111.2	Natural variation among stands	..	..	..	..	1	..	..	..	..	1
111.3	Natural variation among individuals	4	..	..	1	..	1	..	1	..	7
112.0	Induced variation by recombination	..	..	..	..	..	1	..	..	..	1
112.01	Interspecific hybridization	1	1	1	..	..	1	..	..	1	5
112.02	Intraspecific hybridization	..	..	..	..	..	1	..	..	..	1
112.03	Selfing	..	..	..	..	1	..	..	..	..	1
122.0	Seed production areas	..	..	..	..	1	..	..	..	..	1
122.1	Seed orchards	..	..	..	..	2	1	..	..	..	3
14	Fundamental genetic studies	..	..	..	..	..	..	..	1	..	1
141	Mode of inheritance	1	..	..	1	..	..	..	1	..	3
142	Reaction range	..	..	..	..	..	..	..	1	..	1
151.0	Physiology	2	..	..	..	2	..	..	..	..	4
151.01	Flower induction	..	..	..	..	3	1	..	..	..	4
151.02	Vegetative propagation	..	..	..	1	5	5	..	1	..	12
151.03	Nutritional studies	..	..	..	..	1	..	..	..	..	1
151.04	Photoperiodism	..	..	..	..	2	2	..	..	..	4
151.3	Morphology and anatomy	2	..	..	..	..	..	..	..	..	2
151.31	Flower primordia	..	..	..	..	2	..	..	..	..	2
151.32	Wood characteristics	..	..	..	..	2	..	..	1	..	3
151.321	Wood density	..	..	..	..	1	..	..	..	..	1
151.5	Pathology	1	..	..	..	..	5	..	1	..	7
152.0	Entomology	1	..	..	..	1	..	..	..	..	2
153	Biometry	..	..	..	..	1	..	..	1	..	2
154.0	Controlled pollination	..	..	..	..	1	..	..	..	..	1
154.02	Pollen storage	2	..	..	..	..	..	..	..	..	2
154.2	Nursery techniques	..	..	..	..	2	2	..	..	..	4
	Total	24	1	1	4	33	23	2	11	1	100

[1] Applying to all pine species.

Table 4B.--*Picea* projects by categories and species

	Categories	*abies*	*glauca*	*mariana*	*pungens*	*rubens*	Other	Genus[1]	Total
111.0	Natural variation among species	1	1	1	..	1	1	..	5
111.1	Natural variation among races	2	5	2	2	1	1	1	14
111.3	Natural variation among individuals	..	1	..	..	..	..	..	1
112.0	Induced variation by recombination	..	1	1	..	1	1	..	4
122	Seed production	..	1	..	..	..	..	..	1
151.02	Vegetative propagation	..	1	..	..	..	..	1	2
151.04	Photoperiodism	..	2	2	..	..	..	..	4
151.05	Thermoperiodism	..	1	..	..	..	..	..	1
151.08	Phenology	..	1	..	..	..	..	..	1
154.0	Controlled pollination	..	1	1	..	1	1	..	4
154.02	Pollen storage	2	2	..	..	..	..	..	4
154.2	Nursery techniques	..	2	2	..	..	..	..	4
	Total	5	19	9	2	4	4	2	45

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[1] Applying to all spruce species.

A General Summary

The information summarized in the tables gives the following general picture of current forest tree improvement research in the Lake States:[2]

1. Almost three-quarters (74 percent) of the projects are concerned with 3 genera, in this order, *Pinus*, *Picea*, and *Populus*. Some 16 percent of the studies deal with 12 other genera, and about 10 percent are general in nature.

2. The jack, red, and white pines native to the Lake States are involved in 77 percent of the studies on the pines. *Pinus resinosa* is receiving greatest attention (35 percent of the pine studies); *P. banksiana* (22 percent), and *P. strobus* (20 percent) are receiving about equal attention. Several exotic pines are included in the rest of the studies.

3. Among the projects involving spruces, white spruce (*Picea glauca*) is included in 44 percent, black spruce (*P. mariana*) in 19 percent, and Norway spruce (*P. abies*) in 12 percent. Several exotic species and genuswide studies make up the other 25 percent.

4. Studies of variation make up about 50 percent of the total. More than one-third of these concern racial variation. Fundamental genetics studies are about 5 percent of the total. The remaining 45 percent of the studies are in the category of supporting sciences and special techniques, most of them in botany--about half in physiology.

5. Not only do the number of studies involving the pines exceed those of any other genus but also more subject-matter categories are represented in these studies than for those of other genera. For example, 29 subject-matter categories are included in the studies involving the pines compared to 19 for the poplars and 12 for the spruces.

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[2] The proportion of studies assigned to various species or categories can also be calculated considering each numbered study only once (in the tables each study is listed for each species or category included in it). This will give different percentage values but will not change the overall picture presented in the following statements.

Subject-Matter Classification of Forest Tree Improvement Research Projects

1	I. Softwoods
11	A. Selection and testing of variation
111	1. Natural variation
111.0	a. Among species
111.1	b. " races (ecotypes)
111.2	c. " stands
111.3	d. " individuals
112	2. Induced variation
112.0	a. By recombination
112.01	(1) Interspecific hybridization
112.02	(2) Intraspecific "
112.03	(3) Selfing
112.1	b. By mutation
112.11	(1) Physical treatments (radiation, etc.)
	(2) Chemical " (colchicine, etc.)
12	B. Utilization of selected variants for planting by production of
121	1. Clonal lines
122	2. Seed
122.0	a. Seed production areas
122.1	b. Seed orchards
122.2	3. Registered seed
13	C. Applications of genetics in silviculture and management of naturally reproduced stands
14	D. Fundamental genetic studies
141	1. Mode of inheritance
142	2. Reaction range
143	3. Experimental taxonomy
144	4. Evolution
15	E. Supporting sciences and special techniques
151	1. Botany
151.0	a. Physiology
151.01	(1) Flower induction
151.02	(2) Vegetative propagation
151.03	(3) Nutritional studies
151.04	(4) Photoperiodism
151.05	(5) Thermoperiodism
151.06	(6) Chemistry
151.07	(7) Drought resistance
151.08	(8) Phenology
151.09	(9) etc...............
151.1	b. Cytology
151.11	(1) Chromosome numbers
	(2) etc...............
151.2	c. Taxonomy
	(1) etc...............
151.3	d. Morphology and anatomy
151.31	(1) Flower primordia
151.32	(2) Wood characteristics

151.321	(a) Density
151.322	(b) Fiber length
151.323	(c) Fibril angle
151.324	(d) Heartwood, sapwood
151.325	(e) Compression wood
151.331	(1) Agamospermy
	(2) etc............
151.332	(1) Vegetative reproduction
	(2) etc............
151.34	(1) Leaves
	(2) etc............
151.4	e. Ecology
151.5	f. Pathology
152	2. Zoology
152.0	a. Entomology
153	3. Biometry
154	4. Special techniques
154.0	a. Controlled pollination
154.01	(1) Pollen collection
154.02	(2) Pollen storage
154.03	(3) Bagging
154.04	(4) Methods
154.1	b. Climbing gear
154.2	c. Nursery techniques
2	II. Hardwoods
21	A. Selection and testing of variation
211	1. Natural variation
211.0	a. Among species
211.1	b. " races (ecotypes)
	(As in Softwoods)
251.325	c. Tension wood

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Numbers refer to research agencies

Abies

151.02	Vegetative propagation, 5

Acer

211.3	Natural variation among individuals, 11
251.5	Pathology, 11

Betula

211	Natural variation, 10
211.0	Natural variation among species, 10
212.01	Interspecific hybridization, 10
243	Experimental taxonomy, 10
251.04	Photoperiodism, 10

Celtis

251.02	Vegetative propagation, 10

Fraxinus

251.32	Wood characteristics, 7

Juniperus

111.3	Natural variation among individuals, 11
151.5	Pathology, 11

Larix

111	Natural variation, 2
111.1	Natural variation among races, 3, 8, 9
112.01	Interspecific hybridization, 2

Picea

111.0	Natural variation among species, 8
111.1	Natural variation among races, 3, 4, 8, 10
111.3	Natural variation among individuals, 1
112.0	Induced variation by recombination, 8
122	Seed production, 1
151.02	Vegetative propagation, 8, 10
151.04	Photoperiodism, 8, 10
151.05	Thermoperiodism, 8
151.08	Phenology, 8
154.0	Controlled pollination, 8
154.02	Pollen storage, 6, 10
154.2	Nursery techniques, 8, 10

Pinus

11	Selection and testing of variation, 10
111	Natural variation, 10
111.1	Natural variation among races, 3, 4, 8, 9, 10, 11
111.2	Natural variation among stands, 3
111.3	Natural variation among individuals, 8, 10, 11
112.0	Induced variation by recombination, 11
112.01	Interspecific hybridization, 3, 8
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112.03	Selfing, 11
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153 Biometry, 10
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Populus

211 Natural variation, 2
211.0 Natural variation among species, 9, 11
211.3 Natural variation among individuals, 10
212 Induced variation, 2
212.0 Induced variation by recombination, 10, 11
212.01 Interspecific hybridization, 3
221 Production of clonal lines, 10
241 Mode of inheritance, 10
242 Reaction range, 10
251.0 Physiology, 2
251.02 Vegetative propagation, 10
251.04 Photoperiodism, 10
251.3 Morphology and anatomy, 10
251.32 Wood characteristics, 2, 7
251.321 Wood density, 7
251.325 Tension wood, 7
251.4 Ecology, 2
251.5 Pathology, 11
254.2 Nursery techniques, 10

Quercus

211.3 Natural variation among individuals, 11
251.02 Vegetative propagation, 11

Salix

212.01 Interspecific hybridization, 3

Tilia

251.02 Vegetative propagation, 10
251.3 Morphology and anatomy, 10

Tsuga

111.1 Natural variation among races, 8

Ulmus

211.3 Natural variation among individuals, 10
212.01 Interspecific hybridization, 10
251.02 Vegetative propagation, 10
251.5 Pathology, 10

General
(Softwoods)
111 Natural variation, 10
111.0 Natural variation among species, 3, 5, 8, 11
122 Seed production, 8
122.1 Seed orchards, 11
151.02 Vegetative propagation, 2
151.32 Wood characteristics, 7
152.0 Entomology, 8
153 Biometry, 3
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211 Natural variation, 10
211.0 Natural variation among species, 8, 11
222 Seed production, 8
251.02 Vegetative propagation, 2
251.32 Wood characteristics, 7

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